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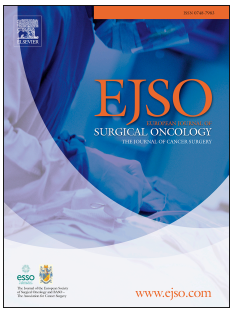

Prevalence, incidence, and risk factors for shoulder and neck dysfunction after neck dissection: a systematic review

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ABSTRACT

Introduction: Shoulder pain and dysfunction may occur following neck dissection among people being treated for head and neck cancer. This systematic review aims to examine the prevalence and incidence of shoulder and neck dysfunction after neck dissection and identify risk factors for these post-operative complications.

Methods: Electronic databases (Pubmed, CINAHL, EMBASE, Cochrane) were searched for articles including adults undergoing neck dissection for head and neck cancer. Studies that reported prevalence, incidence or risk factors for an outcome of the shoulder or neck were eligible and assessed using the Critical Review Form – Quantitative studies.

Results: Seventy-five articles were included in the final review. Prevalence rates for shoulder pain were slightly higher after RND (range, 10-100%) compared with MRND (range, 0-100%) and SND (range, 9-25%). The incidence of reduced shoulder active range of motion depended on surgery type (range, 5-20%). The prevalence of reduced neck active range of motion after neck dissection was 1-13%. Type of neck dissection was a risk factor for shoulder pain, reduced function and health-related quality of life.

Conclusions: The prevalence and incidence of shoulder and neck dysfunction after neck dissection varies by type of surgery performed and measure of dysfunction used. Pre-operative education for patients undergoing neck dissection should acknowledge the potential for post-operative shoulder and neck problems to occur and inform patients that accessory nerve preservation lowers, but does not eliminate, the risk of developing musculoskeletal complications.

Keywords: neck dissection, head and neck neoplasms, shoulder pain, neck pain, quality of life, risk factors

INTRODUCTION

Head and neck cancer encompasses tumours of the upper aerodigestive tract and the skin of the region. Surgical management may include the removal of lymph nodes from the neck, referred to as a neck dissection (ND). The most aggressive form of this procedure is the radical ND (RND) [1], whereby the accessory nerve (CNXI), sternocleidomastoid muscle and internal jugular vein (in addition to lymph nodes) are excised. It is therefore feasible that patients may experience variable degrees of shoulder and neck dysfunction following RND.

Sacrifice of the CNXI during RND is considered a critical factor in determining post-operative shoulder function. Injury to the CNXI and subsequent denervation of the trapezius muscle reduces capacity to elevate the shoulder girdle (scapular dyskinesis), and has been associated with patient reported shoulder pain [2-5], functional loss [6], and reduced health-related quality of life (HRQOL) [7]. Furthermore, greater levels of shoulder disability and reduced HRQOL have been reported in patients following CNXI-sacrificing ND, than in those who underwent CNXI-preserving procedures [8].

While injury to the CNXI appears to be an important risk factor for the development of shoulder dysfunction following ND, it doesn't appear to explain the complete clinical picture in these patients post-operatively. Existing evidence demonstrates that shoulder impairment can still occur even when the CNXI has been preserved [9]. Furthermore, the implications of sternocleidomastoid muscle excision (or denervation following CNXI injury) during ND has not been determined with regard to neck function (and potential neck pain and disability) post-operatively. Clearly there is a need to better understand shoulder and neck dysfunction after both CNXI-preserving and CNXI-sacrificing procedures.

The purpose of this systematic review was to further investigate the relationship between ND surgery and post-operative shoulder and neck dysfunction. Specifically the aims of the systematic review were to: i) identify the prevalence and incidence of shoulder and neck dysfunction after ND; and ii) identify potential risk factors for shoulder and neck dysfunction after ND. We anticipate this systematic review will be informative to the future management of patients undergoing ND for head and neck cancer.

METHODS

The protocol for this systematic review was registered on PROSPERO prior to commencement of the study (#CRD42014012982) and this report has been prepared in line with PRISMA guidelines [10].

Search strategy

Four electronic databases (Pubmed, CINAHL, EMBASE, Cochrane) were searched from inception to 1 January 2016.

The search strategy combined keywords for the population (neck dissection) and body region (shoulder, neck) (see Appendix 1). The reference lists of included studies and relevant systematic reviews were screened and forward citation tracking was conducted to identify any additional studies missed by the database search. Two grey literature databases (OpenGrey and NYAM) were also searched from inception to 1 January 2016 to identify any relevant material (e.g. conference proceedings, governmental reports) from reputable sources.

Eligibility criteria

Studies which met the following criteria were included: cross-sectional, cohort (prospective or retrospective) or case-control design; adults with a history of head and neck cancer and surgically managed with ND; results reporting the prevalence, incidence or risk factors for neck or shoulder dysfunction. Authors were contacted for full text publications if conference abstracts were retrieved by the search. No language restrictions were applied and translations were obtained as required.

Studies eligible for this review could report on any of the following: i) any motor and/or sensory impairment of the neck/shoulder region; ii) altered levels of neck/shoulder function (self-reported or physical assessment); or iii) altered HRQOL associated with the neck/shoulder region. Studies were excluded if they reported only neurophysiological measures (e.g. electromyography) without consideration of clinical outcomes or functional deficits of the neck and shoulder (e.g. pain, physical dysfunction, disability).

Study selection, data extraction and quality assessment

Two health professionals independently screened i) titles and abstracts (EG, KJ) and ii) full texts (EG, MC) to determine their eligibility. Two authors (EG, MC) then independently extracted the data (see Appendix 2) and conducted the quality assessment of included studies using the Critical Review Form – Quantitative Studies

[11]. This methodological assessment tool is applicable to the study designs of interest in this review (cross-sectional, cohort, case-control) and is accompanied by detailed user guidelines [11]. The user is prompted to grade a criterion as being achieved (1), not achieved (0), or not addressed (also 0), and is heavily influenced by what the authors of the included studies report. Authors should report when outcome measures with evidence to support their validity and reliability have been used to satisfy the criteria of using valid and reliable outcomes [11]. If an outcome measure was not described as having supporting evidence for validity and reliability, the criteria were considered 'not addressed', regardless of whether such evidence is actually in existence. The assessment of risk of bias is based on three components: 1) sample/selection bias (volunteer or referral bias, seasonal bias, attention bias); 2) measurement/detection bias (number of outcome measures used, independent evaluation, recall bias); 3) performance bias (contamination, co-intervention) [11]. Disagreements were resolved by discussion and consultation with a third health professional (author ZM) as required.

Analysis

The review was conducted according to an *a priori* registered protocol. The clinical homogeneity of studies was evaluated qualitatively based on the extracted data (i.e. population characteristics, intervention characteristics and outcomes measured). Analytical processes including the use of Chi-squared statistics, meta-analytic models (random or fixed effects) and forest plots (as described in the registered protocol) were applied if pooling of clinically similar studies was possible. If pooling could not be conducted, a narrative description of the findings will be utilised. The description of ND procedure used in this narrative synthesis followed the ND classification system first published in 1991 [12] and updated in 2002 [1] and 2008 [14]. Under this system, there are six major levels of lymph nodes in the neck [1, 14]. The classification system most recently advocated by the International Head and Neck Scientific Group in 2011 [15] was not used, as this was not implemented in any of the included studies.

RESULTS

Study search results

A total of 3,675 citations were retrieved by the search of electronic databases (Figure 1). Seventy-five studies were included after screening. Cross-sectional studies were the most numerous (n=44), followed by cohort (n=28) and case-control (n=3) designs. Languages other than English included: German (n=5), Mandarin (n=2),

French (n=1), Japanese (n=1), Portuguese (n=1), Serbian (n =1), Spanish (n=1) and Turkish (n=1). Included studies encompassed self-reported measures (pain, function, disability, and HRQOL questionnaires), physical measures (joint range of motion, muscle strength, shoulder posture, sensation), and neurophysiological measures (electromyography) of the neck or shoulder.

Methodological assessment findings

Results of the quality assessment are presented in Table 1. An absence of bias was found in nine of the 75 studies. Frequent cases of the presence of bias were found in the selection of participants. Twenty studies described recruiting their cohorts from the attendees at outpatient clinics, thereby missing those patients lost to medical follow up. Seventeen studies excluded patients with pre-existing shoulder or neck pathology before ND, meaning the number of cases of shoulder or neck dysfunction following surgery in the remaining 55 studies may have included some pre-existing cases of pain or dysfunction. Less than half (30 of 75) of included studies justified their sample size. Of ethical concern was the absence of confirmation that informed consent was gained from participants in 41 studies. Few studies made reference to suitable evidence to support the reliability (22 of 75) and validity (25 of 75) of their outcome measures, or to the limitations of their study (22 of 75).

Study characteristics

Characteristics of included studies are reported in Table 2. Prospective studies typically followed patients for up to two years. Cross-sectional studies commonly included patients from a wide-ranging timeline since surgery (up to 19 years post-surgery [16]). Patients were grouped by surgery type (e.g. RND, MRND, SND) or treated as a single cohort of patients post ND. Most included studies featured small sample sizes (i.e. <100).

Pooling of quantitative data for meta-analysis was not possible for two reasons. Firstly, study cohorts were heterogeneous, with various surgery types and timeframes from surgery present across studies. This would have made it difficult to draw meaningful conclusions using pooled estimates from studies featuring patient samples with different surgical characteristics. Furthermore, some cohorts with longer follow up times were at risk of survivorship bias, having patients with greater disease burden potentially not represented in their samples. Secondly, the terminology used to describe and define outcome measures was inconsistent (for example, shoulder droop). The possible outcome of pooling data from studies with inconsistent terminology may have

lead to a misrepresentation of the true rate of dysfunction, and therefore considered inappropriate in the context of the present review.

Prevalence and incidence of shoulder dysfunction

Forty-five of the 75 included studies reported prevalence (Table 3). The most commonly reported outcomes were shoulder pain, shoulder droop, and loss of shoulder active range of motion. Prevalence rates for shoulder pain were slightly higher after RND (range, 10-100%) [2-5, 17-21] compared with MRND (range, 0-100%) [2-5, 17-19, 21] and markedly higher compared with SND (range, 9-25%) [2, 5, 22]. This pattern was more obvious for shoulder droop, with more patients after procedures involving the CNXI (RND range 44 to 100%, MRND range 0 to 30%, SND II-V 56%) [4, 5, 20, 21, 23] displaying a shoulder droop than patients following SND I-III (13%) [23]. Reductions in shoulder active abduction range were reported in the majority of patients following unilateral (range, 92 to 94%) [18, 20] or bilateral (100%) [20] RND, but only a quarter (23%) [18] of patients following MRND. Active flexion range was affected in fewer patients (54%) [20] following unilateral RND.

Incidence was reported in 22 studies and was limited to outcomes of physical impairment or pain (Table 3). Losses to active shoulder abduction range were conflicting: 100% of patients in a mixed surgical cohort [24] versus 5% after SND II-IV and 25% after SND II-V [25]. Abnormal trapezius muscle electromyography findings were present in all patients following RND (100%) [26] compared with 27 to 78% following MRND [26, 27] and 0 to 85% following SND [25-27]. Preserving the cervical root branches had an effect on the incidence of shoulder pain: 14% of patients who underwent ND with preservation of the cervical root branches had shoulder pain compared with 69% of patients in whom the branches had been resected [28]. No study measured the incidence of self-reported neck or shoulder function.

Prevalence and incidence of neck dysfunction

Fewer studies (n = 17) reported on outcome measures related to the neck (Table 3). The prevalence rates for loss of neck active range of motion reported by Teymoortash and colleagues [29] demonstrated 13% of patients had difficulty rotating towards the non-operated side compared with 3% in the opposite direction. Lateral flexion was affected in an equal percentage of patients (11%) towards and away from the operated side [29]. An earlier study from 1990 [30] described a medium to high limitation on neck rotation range of motion as present in 80%

of their cohort of 55 patients. Six studies reported prevalence rates of 0 to 45% for neck pain in mixed cohorts [31-36]. Incidence rates for reduced neck range of motion were between 34 and 45% of a cohort of patients at 3 to 5 weeks following RND [37]. The incidence of neck pain in a cohort of patients following RND and MRND lowered from 70% at day 1 post-surgery to 3% at 2 months post-surgery [34]. Roh and colleagues demonstrated a difference in the incidence rates for neck pain at 18 months post-surgery based on the status of the cervical root branches [28]. Thirty-seven per cent of patients with their branches preserved reported neck pain compared with 73% of patients who had their branches sacrificed during ND [28].

The results for prevalence and incidence of loss of sensation at the neck should be interpreted with caution, due to lack of consistency in terminology (e.g. hyperesthesia, hyperpathia) and limited information concerning sensation testing procedures (see Online Supplementary Material for further information). Of particular interest is the influence of the cervical plexus on the incidence of loss of sensation at the neck. Dilber and colleagues [38] demonstrated a gradual recovery of sensation from 2 weeks post-surgery (71% of patients impaired) to 6 months post-surgery (41% of patients impaired) in patients with a preserved cervical plexus. This is in contrast to the 100% of patients with resection of the cervical plexus during ND exhibiting a loss of sensation at the neck at the same time points.

Risk factors

Risk factors for an outcome related to the neck or shoulder were reported in 16 studies (for a summary of key findings, see Table 4; for the full listing, see Online Supplementary Material). Five of those studies reported the strength of the association between the significant explanatory variables and the dependent variable [39-43]. The most common significant risk factor for a poor outcome was undergoing ND. For example, patients with a history of ND were 3.43 times more likely to have myofascial pain syndrome compared with patients who had not undergone ND (OR (95% CI) = 3.43 (1.16, 10.17); p = 0.026) [40]. Other treatment-related risk factors included undergoing radioactive iodine treatment as a risk factor for reduced HRQOL (coefficient = -7.182; p = 0.003) [39] and radiation therapy as a risk factor for reduced shoulder function (measured with the Constant Score) (coefficient = -8.7; p = 0.1245) [41]. Although radiation therapy was not significant on its own, the authors describe their predictive modelling as most robust when this variable was included [41]. Patient-related factors such as T3-4 tumour (coefficient = 6.6; p = 0.04) [43]) and hypopharyngeal location were also risk

factors for reduced HRQOL and myofascial pain syndrome (OR (95% CI) = 6.35 (1.58, 25.56); p = 0.009) [40], respectively.

Studies examining mixed cohorts indicated that the specific ND procedure is important in understanding the risk of developing pain. ND inclusive of level V was found to be a risk factor for experiencing neck [28] and shoulder [36] pain post-operatively. Furthermore, undergoing SND II-IV or II-V or MRND, or having a sacrifice of the CNXI during SND II-V or MRND, were risk factors for reporting shoulder or neck pain [44]. In contrast, a prospective cohort study in which only 41 of the 93 (44%) patients required ND as a part of their treatment, concluded that having a history of ND, irrespective of the specific surgical procedure performed, was a risk factor for experiencing either head and neck or shoulder and arm pain at two years following the completion of treatment [45].

Risk factors for experiencing neck symptoms other than pain were reported in one study [44]. Undergoing ND was a risk factor for subjective reports of neck stiffness, constriction, and dissatisfaction with the appearance of the neck [44]. Additionally, neck numbness was associated with undergoing SND II-IV or II-V or MRND, or having sacrifice of the CNXI during an SND II-V or MRND [44].

DISCUSSION

This systematic review appraised and summarised findings from 75 studies in the field. The prevalence rates for shoulder pain were higher after RND (range, 10-100%) [2-5, 17-21] compared with MRND (range, 0-100%) [2-5, 17-19, 21] and SND (range, 9-25%) [2, 5, 22]. However, there is some evidence to suggest an uncertain relationship between extent of surgery and pain-related disability of the shoulder [9] that aligns with the known understanding of the multifactorial nature of pain and disability [46-48]. The large variation in incidence and prevalence rates likely reflects the differences in the methods, analysis and definitions used between studies rather than true differences in the rates. This review also identified a number of important risk factors suggestive of poorer outcomes following ND surgery. In particular the type of ND (including nerve sparing approaches) was the most frequently identified risk factor for undesirable outcomes including shoulder pain [36, 44], decreased HRQOL [49] and decreased shoulder function [41, 50]. Notably, age was not a risk factor for

reduced HRQOL [39, 49], shoulder function [41, 50, 51] or pain [40, 45], indicating post-operative outcomes observed in these patients may not result from age-related degeneration.

Few studies included outcome measures of the neck, however there was sufficient evidence to indicate that the neck should be a region of concern. Reduced active range of motion of the neck was experienced by 1 to 13% of patients following ND [29, 52]. The incidence of neck pain was higher when the cervical plexus was sacrificed (72%) rather than preserved (37%) [28]. Loss of sensation was reported in up to 86% of patients [36]. Signs of central sensitisation were also reported (allodynia, hyperpathia) [28, 35]. Risk factors for ongoing neck disability after ND have not been investigated.

Unfortunately, the lack of standardised terminology and outcome measures precluded any pooling of results and meta-analysis. For example, several studies did not specify whether their measurement of shoulder range of motion was active or passive [17, 26, 37, 53, 54]. Shoulder droop was observed as a dichotomous variable (present/not present) [4, 5, 20, 21, 23, 25, 55, 56], but only one study employed an objective, quantitative procedure of this measure [57]. Three different questionnaire-based outcomes measuring shoulder dysfunction were used across four studies [41, 50, 51, 57], giving a different impression of patient experience in each case, hence pooling of results was considered implausible.

The current review has presented a wide-ranging investigation of the current literature, with some limitations, and was generally consistent with the findings reported in a previous scoping review conducted by Goldstein and colleagues [8]. Methodological strengths of the present review include the comprehensive search strategy inclusive of electronic and grey literature databases as well as forward citation searching to cover the width and breadth of previously published research. Articles in languages other than English were included as full text articles and translated by bilingual health professionals. In addition to any other discrepancies between studies, inconsistencies between studies in use of terms such as “extended radical neck dissection” and “super selective neck dissection” without clear anatomical description further complicated any attempt to generate pooled effect estimates using meta-analyses. The choice to use the ND classification system advocated by Robbins and colleagues [1, 12, 14] instead of the more recent recommendations by the International Head and Neck Scientific Group [15] was made because the included studies used the Robbins and colleagues system. We do not anticipate any impact on the findings of this review because of this choice. Goldstein and colleagues also

reported on the variable nature of the outcomes and the study designs, and called for the identification of risk factors for shoulder dysfunction using consistent outcomes across studies [8].

The Critical Review form for quantitative studies was selected as the methodological assessment tool in this study for its suitability to observational study designs, however the tool has several limitations. Developed by the McMaster University Occupational Therapy Evidence-Based Practice Research Group [11], the tool has been used in a number of systematic reviews [58-63]. The flexibility of the tool allows for the assessment of cross-sectional, cohort and case-control studies without modification. However, there is no "gold standard" assessment tool for epidemiological studies [64]. Recommendations have been made for quality assessment tools to avoid a summary score as weighting of results may be variable [64] and categorisation often arbitrary. Previous systematic reviews assessing the effectiveness of an intervention have applied a summary score to the Critical Review Form and also employed levels of evidence in their assessment, for example the National Health and Medical Research Council (NHMRC) levels of evidence [65]. The NHMRC system as well as the Grades of Recommendation, Assessment, Development and Evaluation (GRADE) [66] system are better applied to randomised controlled trials than they are to epidemiological studies. In the present study, the absence of bias from the included studies has been highlighted for the reader (Tables 1 and 3) as further indication of the quality of a study.

This review has highlighted a number of opportunities for future research in this field. Studies to date have focused on risk factors for shoulder pain that are unlikely to be modifiable, such as type of ND or use of ND in patient management. Other potential modifiable risk factors such as reduced pre-operative shoulder mobility or function may be of value for the early identification of patients who may be more likely to develop shoulder or neck dysfunction following surgery. In this manner timely pre-operative (or early post-operative) intervention may be instigated for these patients to minimise any detrimental effects of ND. This review also identified the need for more research into the impact on neck function following ND, particularly as the shoulder and neck have such a strong biomechanical and functional relationship. The role of radiation therapy in determining post-operative shoulder and neck outcomes also remains unclear. Some studies found radiation therapy to be a risk factor for poor outcomes [36, 41]; whilst others found radiation therapy did not cause extra morbidity on top of what resulted from the ND itself [40, 45, 51, 57, 67-69]. Hand dominance could also be investigated as a risk

factor for poor shoulder functional outcomes in the future, as could the order of treatment delivery (surgery/radiation therapy versus radiation therapy/surgery).

CONCLUSION

The prevalence and incidence of shoulder and neck dysfunction after ND varied by type of surgical procedure performed and outcome measures explored. The specific ND surgery undertaken appears to be an important risk factor for determining the likelihood of experiencing post-operative shoulder dysfunction. The findings from this review may be useful for informing the development of pre-operative education programmes for patients awaiting ND, which specifically acknowledge the potential for post-operative shoulder and neck musculoskeletal complications. Furthermore, patients should be made aware that preserving the CNXI may lower, but not eliminate, the risk of such complications.

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CONFLICT OF INTEREST STATEMENT

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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TABLES

Table 1: Results of the quality assessment using the Critical Review Form – Quantitative Studies [11].

Lead author, year	**No bias**	Purpose	Background	Design	Sample detail	Sample size	Consent	Reliability	Validity	Investigation detail	Results as statistics	Statistics appropriate	Clinical importance	Appropriate conclusions	Clinical implications	Study limitations
Agha-Mir-Salim [70] (2002)	**0**	1	1	1	0	0	0	0	0	1	1	1	1	1	1	0
Ahlberg [71] (2012)	**1**	1	1	1	1	1	1	0	0	1	1	1	0	1	1	1
Almeida [39] (2009)	**0**	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
Blessing [53] (1986)	**0**	0	1	0	0	0	0	0	0	0	0	0	1	1	1	0
Busch [17] (1985)	**0**	0	1	0	0	0	0	0	0	0	0	1	1	1	1	1
Campos [24] (1996)	**0**	1	1	1	1	0	1	0	0	1	0	1	0	1	0	0
Cappiello [25] (2005)	**0**	1	1	1	1	0	1	0	0	1	1	1	0	0	1	0
Cardoso [40] (2014)	**0**	1	1	1	1	0	1	0	0	0	1	1	0	1	1	1
Carenfelt [18] (1981)	**0**	0	1	0	1	0	1	0	0	1	0	0	1	0	0	0
Carr [72] (2009)	**0**	1	1	1	1	1	0	1	1	1	1	1	0	0	1	0
Caversaccio [73] (2003)	**0**	1	1	1	1	0	1	0	0	1	1	1	0	0	0	0
Celik [55] (2009)	**1**	1	1	1	1	0	1	0	0	1	1	1	0	0	1	0
Chan [74] (2015)	**0**	1	1	1	1	1	0	1	1	1	1	0	0	0	1	1

Lead author, year	**No bias**	Purpose	Background	Design	Sample detail	Sample size	Consent	Reliability	Validity	Investigation detail	Results as statistics	Statistics appropriate	Clinical importance	Appropriate conclusions	Clinical implications	Study limitations
Chaplin [45] (1999)	**0**	1	1	1	1	0	0	1	1	1	1	1	0	1	1	0
Chen [75] (2015)	**0**	1	1	1	1	1	1	0	0	1	1	1	0	0	1	1
Cheng [26] (2000)	**1**	1	1	1	0	0	0	0	0	1	1	0	0	0	0	1
Chepeha [41] (2002)	**0**	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
Cho [76] (2015)	**0**	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1
Dedivitis [77] (2011)	**0**	1	1	1	1	1	0	0	0	1	0	1	0	1	1	0
Dijkstra [42] (2001)	**0**	1	1	1	1	0	0	0	0	1	1	1	0	0	0	1
Dilber [38] (2007)	**1**	1	1	1	1	0	1	1	1	1	1	1	0	1	1	0
Eickmeyer [67] (2014)	**0**	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1
El Ghani [19] (2002)	**0**	1	1	1	1	0	1	0	0	1	1	1	0	1	1	1
Erisen [68] (2004)	**1**	1	1	1	0	0	1	0	0	1	1	1	0	1	0	0
Ewing [20] (1952)	**0**	0	0	1	1	0	0	0	0	0	0	0	1	1	1	0
Gallagher [49] (2015)	**0**	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1
Guldiken [69] (2005)	**0**	0	1	0	1	0	1	1	1	0	1	1	0	0	0	1
Hamming [78] (1988)	**0**	1	1	1	1	1	0	0	0	1	0	0	0	1	1	0
Hamming [79] (1989)	**0**	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1

Lead author, year	**No bias**	Purpose	Background	Design	Sample detail	Sample size	Consent	Reliability	Validity	Investigation detail	Results as statistics	Statistics appropriate	Clinical importance	Appropriate conclusions	Clinical implications	Study limitations
Hillel [80] (1989)	**0**	1	1	1	1	1	1	0	0	1	1	0	1	1	1	1
Inoue [44] (2006)	**0**	1	1	1	1	0	1	1	1	1	1	1	0	1	1	0
Karabulut [81] (2013)	**0**	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1
Kessler [30] (1990)	**0**	0	1	0	0	0	0	0	0	0	0	1	1	0	1	0
Krause [82] (1992)	**0**	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Kupferman [83] (2004)	**0**	1	1	1	1	0	0	0	0	1	1	0	1	0	1	0
Leipzig [56] (1983)	**0**	1	1	1	0	1	0	0	0	1	0	0	1	0	1	1
Luan [2] (2006)	**0**	1	0	1	1	0	0	1	1	1	1	1	0	1	1	0
Merve [50] (2009)	**0**	1	1	1	1	0	1	0	1	1	1	1	0	1	1	1
Miyata [84] (1997)	**0**	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Murer [85] (2011)	**0**	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
Oz [31] (2009)	**0**	1	1	1	1	0	0	1	0	1	1	1	0	1	0	0
Patten [86] (1993)	**0**	0	1	1	1	0	1	0	0	0	0	0	1	1	1	0
Pinsolle [6] (1997)	**0**	1	1	1	1	1	0	0	0	1	0	0	1	1	1	0
Polistena [87] (2015)	**0**	1	1	1	1	1	0	0	0	1	1	0	0	0	0	1
Prim [88] (2006)	**0**	1	1	0	1	1	0	0	0	1	1	1	0	1	0	0

Lead author, year	**No bias**	Purpose	Background	Design	Sample detail	Sample size	Consent	Reliability	Validity	Investigation detail	Results as statistics	Statistics appropriate	Clinical importance	Appropriate conclusions	Clinical implications	Study limitations
Roh [28] (2007)	**1**	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0
Saunders [16] (1985)	**0**	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0
Sesterhenn [32] (1977)	**0**	1	1	1	0	0	0	0	0	1	0	1	1	1	1	0
Shah [33] (2001)	**0**	1	1	1	1	1	1	0	1	1	1	1	0	0	1	0
Sheikh [89] (2014)	**0**	0	1	1	0	0	1	0	0	0	1	1	0	1	0	1
Shone [90] (1991)	**0**	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0
Short [3] (1984)	**0**	1	1	1	1	0	0	0	0	1	1	1	0	1	1	0
Siddiquee [54] (2007)	**0**	1	1	0	1	0	0	0	0	1	0	0	0	1	0	0
Stearns [21] (1981)	**0**	1	1	1	0	0	0	0	0	1	0	1	0	0	0	0
Stew [22] (2014)	**0**	1	1	1	0	1	0	0	0	0	1	0	0	0	0	1
Stuiver [51] (2008)	**0**	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1
Talmi [34] (2000)	**0**	1	1	0	1	0	1	0	0	1	0	0	0	1	0	0
Tarkan [91] (2012)	**0**	1	1	1	0	0	1	0	0	1	1	1	0	0	0	0
Terrell [43] (2000)	**0**	1	1	1	1	0	1	1	1	1	1	1	0	1	1	1
Teymoortash [29] (2010)	**0**	1	1	1	1	0	0	0	0	1	1	1	1	1	0	1
Thumfart [52] (1977)	**0**	1	1	1	1	1	0	0	0	0	0	0	1	1	1	0

Lead author, year	**No bias**	Purpose	Background	Design	Sample detail	Sample size	Consent	Reliability	Validity	Investigation detail	Results as statistics	Statistics appropriate	Clinical importance	Appropriate conclusions	Clinical implications	Study limitations
Trivić [4] (2009)	**1**	1	1	1	0	1	0	0	0	0	1	1	1	1	1	0
Umeda [92] (2010)	**0**	1	1	1	1	0	0	0	0	1	0	1	0	0	0	0
Urist [93] (1983)	**0**	1	1	1	1	1	1	0	0	0	1	1	0	1	1	1
van Wilgen [23] (2003)	**0**	1	1	1	1	0	1	0	0	1	1	1	0	1	0	1
van Wilgen [94] (2003)	**0**	1	1	1	1	1	0	1	1	0	1	1	0	1	0	0
van Wilgen [35] (2004)	**0**	1	1	1	1	1	0	0	0	1	1	1	0	1	1	1
van Wilgen [9] (2004)	**0**	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1
van Wouwe [57] (2009)	**0**	1	1	1	1	0	0	0	1	1	1	1	0	1	1	0
Wang [36] (2009)	**1**	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1
Watkins [95] (2011)	**0**	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1
Witt [27] (2007)	**1**	1	0	1	0	0	0	0	0	1	1	0	0	1	1	1
Yamada [37] (1965)	**0**	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0
Zhang [5] (2004)	**0**	1	0	1	1	1	0	0	0	0	1	1	1	1	1	1
Zibordi [96] (1988)	**0**	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0

Table 2: Characteristics of included studies.

Lead author, year	Study type and timing of assessments	Participants (n, surgical types, withdrawals for prospective cohort studies)	Continuous variables of interest
Agha-Mir-Salim [70] (2002)	Prospective cohort; Pre-surgery, 2 weeks, 1 month, 3 months and 6 months post-surgery.	N = 40; RND, MRND; Withdrawals not listed.	No continuous variables were reported in this study.
Ahlberg [71] (2012)	Prospective cohort; At the cessation of EBRT and 2 months, 6 months and 12 months post-cessation of EBRT.	N = 234; SND I-III, MRND; Withdrawals n = 28.	At 12 months post-surgery, neck rotation AROM mean (SD): SND I-III 117° (22.0°), MRND 106° (20. 2°); Neck lateral flexion AROM mean (SD): SND I-III 61° (17.2°), MRND 52° (14.4°). Neck flexion-extension AROM mean (SD): SND I-III 101° (16.7°), MRND 90.4° (18.5°).
Almeida [39] (2009)	Cross-sectional; 9 year period of hospital records.	N = 154; SND II-IV, II-VI and VI only.	Composite UW QOL score median (range): 93.05 (53.5-100).
Blessing [53] (1986)	Cross-sectional; Mean 2.6 years post-surgery.	N = 23 (29 total NDs); MRND.	No continuous variables were reported in this study.
Busch [17] (1985)	Cross-sectional; Mean 2.25 years post-surgery (range 6-42 months).	N = 28; RND, MRND.	Shoulder abduction ROM of the operated side as a percentage of the non –operated side mean (range): 92.8% (70.6-114.3%)
Campos [24] (1996)	Prospective cohort; More than 1 year.	N=12; RND, FND; Withdrawals n = 23.	Shoulder abduction AROM median: RND 76°, FND 98°. Shoulder abduction PROM median: RND 121°, FND 140°.
Cappiello [25] (2005)	Retrospective cohort; At least 1 year post-surgery.	N = 40; Groups: SND II-IV, II-V.	Electroneurographic findings are reported on a continuous scale, however the reported values have not been defined (e.g. no indication of whether number represents mean or median).
Cardoso [40] (2014)	Cross-sectional; At least 1 year post-surgery.	N = 167; SND, RND.	Composite UW QOL score mean (SD): patients with myofascial pain syndrome 83.7 (15.0), patients without myofascial pain syndrome 83.9 (13.9).

Carenfelt [18] (1981)	Cross-sectional; Range 2-7 years post-surgery.	N = 53; RND, MRND.	Relative shoulder abduction strength of the affected arm as a percentage of the unaffected arm mean (range): RND 52% (25-91%), MRND with major paresis 52% (40-62%), MRND with minor paresis 75% (46-100%), MRND with no paresis 96% (82-120%).
Caversaccio [73] (2003)	Case-control; Timing not listed.	N = 34; RND, MRND.	Constant Shoulder score mean (SD): RND 54.3 (11.9), MRND 84.3 (10.2).
Carr [72] (2009)	Cross-sectional; Mean 1.6 years post-surgery (range 0.5-4 years).	N = 65; SND I-III, extended SND I-III, SND II-IV.	DASH score mean (SD) (range): SND I-III 25.1 (25.9) (0-97.5), extended SND I-III 15.7 (16.2) (0-46.4), SND II-IV 11.9 (15.0) (0-45.3).
Celik [55] (2009)	Prospective cohort; Pre-surgery, 21 days and 6 months post-surgery.	N = 30; Level IIb-preserving SND; Withdrawals not listed.	ROM at 6 months mean ± SEM: shoulder flexion 169.48° ± 3.35°, shoulder abduction 167.94° ± 3.91°, neck rotation 54.74° ± 1.79°.
Chan [74] (2015)	Prospective cohort; 1 year and 2 years post-surgery.	N = 92; SND I-III plus V; No withdrawals.	DASH score mean (SD) (range) score: at 1 year 44.2 (10.1) (28.0-66.5%), at 2 years 46.3 (12.4) (22.3-70.5).
Chaplin [45] (1999)	Prospective cohort; Diagnosis, 3 months, 12 months and 24 months post-treatment (surgery or XRT).	N = 201; ND; Withdrawals n = 108.	Mean pain scores presented graphically.
Chen [75] (2015)	Prospective cohort; Median 36 months post-surgery (range 12-77 months).	N = 69; RND, SND I-IV; Withdrawals n = 15.	No continuous variables were reported in this study.
Cheng [26] (2000)	Prospective cohort; Pre-surgery, 1 month and 6 months post-surgery.	N = 21; RND, MRND, SND; Withdrawals not listed however authors excluded incomplete data sets.	Isokinetic peak toque of shoulder abduction at 60°/s at 6 months after surgery mean ± SEM: SND 17.8 ± 4.6 foot-pounds, MRND 16.1 ± 6.8 foot-pounds, RND 10.6 ± 2.8 foot-pounds.
Chepeha [41] (2002)	Cross-sectional; Mean 33.7 months (range 11-120 months) post-surgery.	N = 54 (64 total NDs); MRND, SND.	Constant Shoulder score mean (SD) (range): 71.0 (18.8) (22-100).
Cho [76] (2015)	Cross-sectional; Median 5 years post-surgery (range 1.1-9.2 years).	N = 42; RND, MRND, SND.	SDQ score mean (SD): RND 10.90 (4.75), MRND and SND 1.82 (2.96). Trapezius muscle volume ratio mean (SD): RND 0.37 (0.18),

			MRND and SND 0.91 (0.14).
Dedivitis [77] (2011)	Cross-sectional; Timing not listed.	N = 480 (708 total NDs); RND, SND I-III, "jugular" SND.	No continuous variables were reported in this study.
Dijkstra [42] (2001)	Retrospective cohort; The day prior to hospital discharge post-surgery.	N = 177; RND, MRND, SND; The authors acknowledge the "considerable amount of missing data".	Shoulder pain intensity (mm) mean (SD): 14 (16). Shoulder ROM mean (SD): flexion operated side 138.4° (26.3°), non-operated side 159.1° (24.8°); abduction operated side 99.2° (46.6°), non-operated side 145.7° (35.4°); external rotation operated side 59.5° (17.8°), non-operated side 65.1° (17.7°).
Dilber [38] (2007)	Prospective cohort; Pre-surgery, 2 weeks, 1 month, 3 months, 6 months post-surgery.	N = 17; SND II-IV or II-IV plus V.	Shoulder pain intensity (mm) at rest at 6 months post-surgery mean ± SEM: cervical plexus sparing ND 30 ± 1.6, cervical plexus sacrificing ND 47 ± 2.1.
Eickmeyer [67] (2014)	Cross-sectional; At least 5 years since the completion of treatment and at least 3 years disease-free.	N = 105; RND, CNXI-preserving ND.	UW QOL scores for pain domain mean (SD): CNXI-preserving ND 1.70 (0.73), CNXI-sacrificing ND 1.88 (0.62). UW QOL scores for shoulder disability domain mean (SD): CNXI-preserving ND 1.85 (0.76), CNXI-sacrificing ND 2.38 (0.81).
El Ghani [19] (2002)	Cross-sectional; Range 4 months to 5 years post-surgery.	N = 59; RND, MRND, SND I-III.	Difference between shoulder flexion active range of motion for non-operated and operated sides mean (SD): RND 33.5° (24°), MRND 10.7° (16.5°), MRND preserving cervical contributions 4.8° (16.9°). Difference between shoulder abduction active range of motion for non-operated and operated sides mean (SD): RND 76.1° (45.1°), MRND 28.2° (31.2°), MRND preserving cervical contributions 23.8° (47.1°).
Erisen [68] (2004)	Prospective cohort; At least 6 months after surgery or 3 months after adjuvant XRT;	N = 57 (92 total NDs); RND, MRND, SND; Withdrawals not listed.	Loss of shoulder flexion ROM mean: RND 37.8°, MRND/SND 20.0°. Loss of shoulder

	mean 27 months (range 6-71 months); functional testing was conducted between the 4th and 6th month after surgery.		abduction ROM mean: RND 64.1°, MRND/SND 28.1°. Loss of shoulder flexion strength mean: RND 60.9%, MRND/SND 43.5%. Loss of shoulder abduction strength mean: RND 78.3%, MRND/SND 49.3%.
Ewing [20] (1952)	Cross-sectional; At least 6 months post-surgery; n = 51 were 1 to 5 years post-surgery, n = 20 were >5 years post-surgery.	N = 100; RND.	No continuous variables were reported in this study.
Gallagher [49] (2015)	Cross-sectional; At least 12 months post-surgery.	N = 167; MRND, SND.	NDII score median (range): overall 90 (10-100), MRND 85 (30-100), SND 92 (10-100). Constant Shoulder score median (range): MRND 85 (10-100), SND 92 (30-100).
Guldiken [69] (2005)	Prospective cohort; Pre-surgery, 1 month, 3 months, 6 months, and 18 months post-surgery.	N = 25; Bilateral FND; Withdrawals n = 3.	At 18 months post-surgery, NDII score mean (SD) (range): 98.2 (1.98) (95-100).
Hamming [78] (1988)	Retrospective cohort; Retrospective review of 20 years of data.	N = 83; Conservative ND (node picking), extensive dissection (most likely MRND).	No continuous variables were reported in this study.
Hamming [79] (1989)	Retrospective cohort; Timing not listed.	N = 165; Excision of pretracheal and paratracheal nodes, excision of nodes in tracheoesophageal groove (extensive ND).	No continuous variables were reported in this study.
Hillel [80] (1989)	Cross-sectional; Mean 22 months post-surgery (range 9-49 months).	N = 11; RND.	Shoulder abduction AROM mean (SD) (range): sitting operated side 74° (22°) (46°-122°), non-operated side 148° (15°) (120°-165°). Shoulder abduction PROM mean (SD) (range): operated side 121° (26°) (70°-165°), non-operated side 164° (14°) (127°-170°).
Inoue [44] (2006)	Cross-sectional; Mean 36 months post-surgery (range 1-23 years).	N = 74; SND I-III, SND II-IV, SND II-V, MRND.	Arm Abduction Test score mean: SND I-III 3.8, SND II-IV 3.5, SND II-V/MRND 3.2, SND II-V/MRND with CNXI sacrifice 1.6.

Karabulut [81] (2013)	Cross-sectional; Mean (SD) 22 (29.3) months post-surgery (range 12-150 months).	N = 191; Groups: RND, CNXI-preserving ND.	Composite UW QOL score mean (SD): CNXI-preserving ND 87.3 (9.4), CNXI-sacrificing ND 79.4 (10.8).
Kessler [30] (1990)	Cross-sectional; Range up to 15 years post-surgery.	N = 55; ND.	No continuous variables were reported in this study.
Krause [82] (1992)	Cross-sectional; Mean 29 months post-surgery.	N = 54; RND.	No continuous variables were reported in this study.
Kupferman [83] (2004)	Retrospective cohort; Retrospective chart review 1997-2002.	N = 39; MRND, MRND plus level VI.	No continuous variables were reported in this study.
Leipzig [56] (1983)	Prospective cohort; Pre-surgery, immediate post-operative period, 6 months post-surgery.	N = 109; RND, MRND; Withdrawals not listed.	No continuous variables were reported in this study.
Luan [2] (2006)	Cross-sectional; At least 1 year post-surgery.	N = 66; RND, MRND, SND.	NDII score mean (range): RND 43.5 (15-83), MRND 70.4 (27.5-100), SND 87.3 (60-100).
Merve [50] (2009)	Cross-sectional; Minimum 6 months post-surgery.	N = 57; ND.	Constant Shoulder score median (range) with pectoralis major reconstruction: SND 100 (82-100), MRND 80 (48-100), RND 62 (49-100). Constant Shoulder score median (range) without reconstruction: SND 100 (85-100), MRND 98 (85-100), RND 76 (23-98).
Miyata [84] (1997)	Cross-sectional; More than 1 month post-surgery.	N = 15 (20 total NDs); RND, CNXI-preserving ND.	No continuous variables were reported in this study
Murer [85] (2011)	Cross-sectional; Mean 4.6 years post-surgery (range 1-9.3 years).	N = 62; SND, SNB.	NDII score mean (range): SNB 99.7 (90-100), SND 94.3 (32.5-100). Modified Constant score* mean (range): SNB 99.87% (97.3-100%), SND 96.13% (65.3-100%).
Oz [31] (2009)	Case-control; Mean (SD) 1.6 (0.94) years post-surgery (range 1-4 years).	N = 40; CNXI-preserving ND.	Neck pain intensity (cm) mean (SD): 3.0 (1.6). Neck PROM mean (SD): flexion 44.50° (11.34°), extension 33.25° (6.34°), rotation left 68.25° (13.40°), rotation right 63.75° (13.36°). Shoulder PROM mean (SD): flexion left 146.25°

			(30.25°), flexion right 160.50° (25.17°), abduction left 151.00° (30.67°), abduction right 160.25° (21.18°). NPNPQ score mean (SD): 16.35 (16.86). NPDS mean (SD): 12.50 (16.79).
Patten [86] (1993)	Prospective cohort; 1 month, 6 months, 12 months and 18 months post-surgery.	N = 29; CNXI-preserving ND; Withdrawals not listed.	No continuous variables were reported in this study.
Pinsolle [6] (1997)	Prospective cohort; 1 month and 1 year post-surgery.	N = 337 (487 total NDs); RND, FND, SND I-III; Withdrawals n = 14.	No continuous variables were reported in this study.
Polistena [87] (2015)	Retrospective cohort; 25 years of retrospective chart data.	N = 1775; RND, MRND.	No continuous variables were reported in this study.
Prim [88] (2006)	Retrospective cohort; 18 years of retrospective chart data.	N = 442; FND.	No continuous variables were reported in this study.
Roh [28] (2007)	Retrospective cohort; mean 18.7 months post-surgery (minimum 12 months).	N = 53; ND.	Neck pain intensity (cm) mean (SD): ND with preservation of cervical root branches 1.5 (1.4), ND with sacrifice of cervical root branches 3.1 (2.4). Shoulder AROM mean (SD): ND with preservation of cervical root branches flexion 162.4° (20.8°), abduction 158.8° (25.7°) , ND with sacrifice of cervical root branches flexion 155.3° (20.7°), abduction 148.3° (29.5°).
Saunders [16] (1985)	Cross-sectional; Mean 6.2 years post-surgery (range 0.5- 19 years).	N = 100; RND, MRND.	No continuous variables were reported in this study.
Sesterhenn [32] (1977)	Cross-sectional; Patients were also divided into groups by time of surgery: <6 months post-surgery, 6 to 12 months post-surgery, 1 to 2 years post-surgery, >2 years post-surgery.	N = 72; RND, MRND.	No continuous variables were reported in this study
Shah [33] (2001)	Cross-sectional; N = 15 <1 year post-surgery, n = 16 2 -3 years post-surgery, n = 9 3-4 years post-surgery, n = 10 >4 years post-surgery.	N = 51; RND, MRND, SND.	ND-QOL score by time from surgery mean: <11 months 2.01, 12 to 23 months 1.78, 24-35 months 1.62, >36 months 1.24.

Sheikh [89] (2014)	Cross-sectional; Mean (SD) 14.4 (10.9) months post-surgery.	N = 70 (92 total NDs); RND, MRND, SND.	No continuous variables were reported in this study.
Shone [90] (1991)	Cross-sectional; At least 6 months post-surgery.	N = 46; RND.	No continuous variables were reported in this study.
Short [3] (1984)	Cross-sectional; Timing not listed.	N = 43; RND, MRND, conservative ND.	Shoulder pain intensity (0 (no pain) to 5 (severe pain)) mean: CNXI-preserving ND 1.6, CNXI-sacrificing ND 2.7.
Siddiquee [54] (2007)	Retrospective cohort; Timing not listed.	N = 30; RND, MRND.	No continuous variables were reported in this study.
Stearns [21] (1981)	Cross-sectional; Timing not listed.	N = 20; RND, CNXI-preserving ND.	No continuous variables were reported in this study.
Stew [22] (2014)	Cross-sectional; At least 3 months post-surgery.	N = 44; MRND, SND I-IV, SND II-V.	Loss of shoulder flexion ROM mean (SD): SND I-IV 19.8° (20.7°), SND II-V/MRND 28.7° (15.1°). Loss of shoulder abduction ROM mean (SD): SND I-IV 22.8° (22.9°), SND II-V/MRND 29.7° (14.5°).
Stuiver [51] (2008)	Prospective cohort; The day prior to surgery, at discharge from hospital, approximately 4 months post-surgery.	N = 139; RND, MRND, SND; Withdrawals n = 12.	Loss of shoulder flexion AROM median (IQR): pre-surgery to discharge 19° (4, 34), pre-surgery to 4 months post-surgery 20° (0, 40). Loss of shoulder abduction AROM median (IQR): pre-surgery to discharge 34° (1, 102), pre-surgery to 4 months post-surgery 50° (0, 103).
Talmi [34] (2000)	Two retrospective cohort studies and one prospective cohort study reported in the same paper; Retrospective studies: one assessment. Prospective study: Pre-surgery, 24 hours, 48 hours, 72 hours, 1 week post-surgery, on discharge from hospital, 1 week after discharge, 1 month, 3 months and 6 months post-surgery.	N = 88; RND, MRND; Withdrawals n = 1 from the prospective cohort study.	Neck pain score (cm) mean: within 6 to 24 months post-surgery 3.7; at 1 day post-surgery 5.4; at 1 week post-surgery 0.5; at 1 month post-surgery 3.0; at 12 months post-surgery 3.4.

Tarkan [91] (2012)	Cross-sectional; Timing not listed.	N = 29; MRND, SND.	Shoulder AROM mean (SD): flexion 131.9° (27.6°), abduction 130.5° (29.8°).
Terrell [43] (2000)	Cross-sectional; Timing not listed.	N = 397; RND, CNXI-preserving ND.	HNQOL scores for pain domain mean: CNXI-sacrificing ND 51.7, CNXI-preserving ND 66.3. HNQOL scores for shoulder or neck pain item mean: CNXI-sacrificing ND 51.1, CNXI-preserving ND 66.3.
Thumfart [52] (1977)	Cross-sectional; Range 3 months to 10 years post-surgery.	N = 200; RND.	No continuous variables were reported in this study.
Trivić [4] (2009)	Cross-sectional; Participants who underwent surgery between January 2000 and December 2002 and who were subsequently followed for five years post-operatively were included in this study; the authors do not explicitly state when the follow up assessment was conducted.	N = 319; RND, MRND, SND.	No continuous variables were reported in this study.
Umeda [92] (2010)	Cross-sectional; 3 months post-surgery.	N = 90 (105 total NDs); RND, MRND.	No continuous variables were reported in this study.
Urist [93] (1983)	Cross-sectional; At least 6 months post-surgery.	N = 208; RND, MRND.	No continuous variables were reported in this study.
van Wilgen [23] (2003)	Cross-sectional; Mean (SD) 3 (2) years post-surgery.	N = 113; RND, MRND, SND I-III, SND II-IV, SND II-V.	Shoulder pain intensity (cm) mean (SD): operated side 4.2 (2.3), non-operated side 4.2 (2.6). Shoulder abduction AROM mean (SD): operated side 146° (62°), non-operated side 162° (26°).
van Wilgen [94] (2003)	Cross-sectional; Mean (SD) 2.3 (1.3) years post-surgery.	N = 50; SND I-III.	No continuous variables were reported in this study.
van Wilgen [35] (2004)	Cross-sectional; Mean (SD) 3 (1.3) years post-surgery.	N = 153; RND, MRND, SND I-III, SND II-V.	Neck pain intensity (cm) mean (SD): 3.5 (2.3). Shoulder pain intensity (cm) mean (SD): 3.7 (2.3).

van Wilgen [9] (2004)	Cross-sectional; Mean (SD) 3.0 (1.7) years post-surgery.	N = 154; RND, MRND, SND I-III, SND II-IV, SND II-V.	SDQ scores mean (SD): SND II-V 48.6 (35.1), MRND 22.2 (28.6), SND I-III 11.6 (26.1).
van Wouwe [57] (2009)	Cross-sectional; Mean 39 months post-surgery (range 6-122 months).	N = 100; RND, MRND, SND.	Shoulder pain intensity (mm) mean (SD): 18 (42). SDQ scores mean (SD): RND 45 (24), MRND 32 (29), SND 20 (31).
Wang [36] (2009)	Cross-sectional; 1 month post-surgery.	N = 29; ND.	Shoulder pain intensity mean (SD): 4.50 (2.15).
Watkins [95] (2011)	Cross-sectional; Mean (SD) 59 (29) months post-surgery (range 19-100 months).	N = 34; SND.	Constant Shoulder score mean (SD): operated side 75.9 (15.4), non-operated side 87.2 (11.3).
Witt [27] (2007)	Prospective cohort; Intra-operatively, 2 months post-surgery.	N = 22; MRND, SND I-III; Withdrawals not listed.	No continuous variables were reported in this study.
Yamada [37] (1965)	Prospective cohort; 1 day prior to surgery, 3 to 5 weeks post-surgery.	N = 29; RND; Withdrawals n = 23.	At 3 to 5 weeks post-surgery, shoulder AROM mean (SD): abduction 128.8° (19.70°), flexion 122.2° (19.15°).
Zhang [5] (2004)	Cross-sectional; Timing not listed.	N = 32 (43 total NDs); RND, MRND, SND.	No continuous variables were reported in this study.
Zibordi [96] (1988)	Case-control; Mean 3.5 years post-surgery (range 1 month to 10 years 8 months post-surgery).	N = 56; RND, MRND.	No continuous variables were reported in this study.

*Modified Constant score = strength of shoulder abduction in the plane of the scapula measured by manual muscle testing instead of spring balance [85].

ND = neck dissection; RND = radical neck dissection; MRND = modified radical neck dissection; SND = selective neck dissection; FND = functional neck dissection; CNXI = accessory nerve; SNB = sentinel node biopsy; XRT = radiation therapy; EBRT = external beam radiation therapy; SD = standard deviation; SEM = standard error of the mean; IQR = interquartile range; AROM = active range of motion; ROM = range of motion; PROM = passive range of motion; UW QOL = University of Washington Quality of Life (quality of life; range 0 = worst possible response to 100 = best possible response); DASH = Disabilities of the Arm, Shoulder and Hand (arm, shoulder and hand function; range 0 = best possible response to 100 = worst possible response); SDQ = Shoulder Disability Questionnaire (shoulder function; range 0 = best possible response to 100 = worst possible response); NDII = Neck Dissection Impairment Index (quality of life; range 0 = worst possible response to 100 = best possible response); NPNPQ = Northwick Park Neck Pain Questionnaire (neck pain-related disability; range 0 = best possible response to 36 = worst possible response); NPDS = Neck Pain and Disability Scale (pain-related disability; range 0 = best possible response to 100 = worst possible response); HNQOL = Head and Neck Quality of Life (quality of life; range

0 = worst possible response to 100 = best possible response); ND-QOL = Neck Dissection Quality of Life questionnaire (quality of life; range 0 = best possible response to 7 = worst possible response).

Other scales: Constant score = shoulder function (range 0 = worst possible response to 100 = best possible response); Arm Abduction Test = shoulder function (range 0 = worst possible response to 5 = best possible response). Where pain is measured in centimetres, range 0 = no pain to 10 = worst pain imaginable. Where pain is measured in millimetres, range 0 = no pain to 100 = worst pain imaginable.

Table 3: Selection of key results from included studies reporting prevalence or incidence (full listing of results can be found in the Online Supplementary Material).

Outcome	Prevalence	Risk of bias present in x/n studies	Incidence	Risk of bias present in x/n studies
Loss of shoulder abduction AROM	Mixed cohorts: 40 to 97% [23, 29, 32, 82]. Unilateral RND: 92 to 94% [18, 20]. Bilateral RND: 100% [20]. MRND: 23% [18].	4/4 2/2 1/1 1/1	Mixed cohort: 100% at >1 year post-surgery [24]. SND II-IV: 160-180° 5% at >1 year post-surgery [25]. SND II-V: 160-180° 20%; 140-160° 5% at >1 year post-surgery [25].	1/1 1/1 1/1
Loss of shoulder flexion AROM	Unilateral RND: 54% [20].	1/1	-	-
Loss of shoulder abduction PROM	Mixed cohort: 57 to 91% [32, 80]. RND: 50% [21]. CNXI-preserving ND: 0% [21].	2/2 1/1 1/1	Mixed cohort: 92% at >1 year post-surgery [24].	1/1
Loss of shoulder flexion PROM	Mixed cohort: 73% [80].	1/1	-	-
Loss of trapezius muscle strength	CNXI-preserving ND: 0% (upper trapezius)[#]; 55% (middle trapezius)[#]; 64% (lower trapezius)[#] [84]; 11% [96]. CNXI-sacrificing ND and no motor input from CP: 0% (upper trapezius)[#]; 100% (middle trapezius)[#]; 100% (lower trapezius)[#] [84]. CNXI-sacrificing ND and motor input is present from CP: 0% (upper trapezius)[#]; 100% (middle trapezius)[#]; 100% (lower trapezius)[#] [84]. RND: 100% [96].	2/2 1/1 1/1 1/1	SND II-IV: 0% at >1 year post-surgery [25]. SND II-V: 20% at >1 year post-surgery [25].	1/1 1/1
Loss of SCM muscle strength	CNXI-preserving ND: 5% [96].	1/1	-	-

Shoulder droop	Mixed cohort: 15 to 100% [32, 57, 82]. RND: 44 to 100% [4, 5, 20, 21, 23]. Bilateral RND: 46% [20]. CNXI-preserving ND: 0% [21]. MRND: 0 to 30% [4, 5, 23]. SND: 0% [5]. SND II-V: 56% [23]. SND I-III: 13% [23].	4/4 5/6 1/1 1/1 2/3 1/1 1/1 1/1	Mixed cohort: at discharge from hospital 57%; at 4 months post-surgery 52% [51]; Shoulder drop with muscle atrophy: 10% at 6 months post-surgery; Shoulder drop with muscle atrophy and wing scapula: 3.33% at 6 months post-surgery [55]. RND: 86% at 6 months post-surgery [56]. MRND: 35% at 6 months post-surgery [56]. MRND with sacrifice of SCM and IJV: 50% at 6 months post-surgery [56]. SND II-IV: 5% at >1 year post-surgery [25]. SND II-V: 30% at >1 year post-surgery [25].	1/2 1/1 1/1 1/1 1/1 1/1
Atrophy of the upper trapezius muscle	Mixed cohort: 3 to 57% [52, 82]. RND: 100% [23]. MRND: 28% [23]. SND II-V: 56% [23]. SND I-III: 6% [23].	2/2 1/1 1/1 1/1 1/1	Mixed cohort: 13% at 6 months post-surgery [55].	0/1
Shoulder pain	Mixed cohort: 0 to 76% [23, 29, 31, 32, 36, 52, 57, 82, 90, 91]. RND: 10 to 100% [2-5, 17-21]. MRND (CNXI preserved): 0 to 100% [2-5, 17-19, 21]. MRND (CNXI and C2-3 preserved): 100% [19]. SND: 9 to 25% [2, 5]. SND I-IV: 7% [22]. SND II-V/MRND: 25% [22].	9/10 8/9 7/8 1/1 2/2 1/1 1/1	Mixed cohort: 48% at 4 months post-surgery [51]; 70% on the day prior to discharge from hospital following surgery [42]. ND with preserved cervical root branches: 14% at 18 months post-surgery [28]. ND with sacrificed cervical root branches: 69% at 18 months post-surgery [28]. ND with CP preserved: 100% at 6 months post-surgery [38]. ND with CP sacrificed: 100% at 6 months post-surgery [38]. RND: 13% (timeframe not listed) [54]; 60% at 6 months post-surgery; 100% at 6 months post-surgery [26]. MRND: 31% at 6 months post-surgery [56]; 40% (timeframe not listed) [54]; 56% at 6 months post-surgery [26]. RND/MRND with CP sacrificed: 13% at 2 weeks post-surgery; 31% at 6 months post-surgery [70]. RND/MRND with CP preserved: 17% at 2 weeks post-surgery; 17% at 6 months post-surgery [70]. MRND with preservation of CNXI and sacrifice of SCM and IJV: 36% at 6 months post-surgery [56].	2/2 0/1 0/1 0/1 0/1 1/2 2/3 1/1 1/1 1/1

			SND: 29% at 6 months post-surgery [26].	0/1
SDQ score of more than zero	Mixed cohort: 54%* [57]. MRND: 33% [9]. SND II-V: 67% [9]. SND I-III: 20% [9]. CNXI-sacrificing ND: 90%^ [76]. CNXI-preserving ND: 10%^ [76].	1/1 1/1 1/1 1/1 1/1 1/1	-	-
Pain domain of the UW QOL questionnaire	CNXI-sacrificing ND: moderate pain requiring analgesia 6%, severe pain controlled by narcotics 30%, severe pain not controlled by medication 64% [81]. CNXI-preserving ND: moderate pain requiring analgesia 2%, severe pain controlled by narcotics 18%, severe pain not controlled by medication 80% [81].	1/1 1/1	-	-
Shoulder domain of the UW QOL questionnaire	CNXI-sacrificing ND: no problem 1%, shoulder stiffness but no effect on activity or strength 22%, pain or weakness in the shoulder causing the participant to change their work 56%, cannot work due to shoulder problems 21% [81]. CNXI-preserving ND: no problem 0%, shoulder stiffness but no effect on activity or strength 11%, pain or weakness in the shoulder causing the participant to change their work 34%, cannot work due to shoulder problems 55% [81].	1/1 1/1	-	-
Modified Constant score	Mixed cohort: mild 32%, moderate 6%, severe dysfunction 12% [95].	1/1	-	-
DASH questionnaire severity of upper limb dysfunction	Mixed cohort: none 23%, mild 54%, moderate 15%, severe 8% [72]. SND I-III: none 14%, mild 60%, moderate 17%, severe 9% [72]. Extended SND I-III: none 33%, mild 50%, moderate 17%, severe 0% [72].	1/1 1/1 1/1	-	-

	SND II-IV: none 45%, mild 45%, moderate 9%, severe 0% [72].	1/1		
Abnormal trapezius muscle EMG	Mixed cohort: 76% (upper), 44% (middle), 41% (lower) [82].	1/1	Mixed cohort: 40% at 1 month post-surgery; 85% at 18 months post-surgery [86].	1/1
	RND: 100% [96].	1/1	RND: 100% at 6 months post-surgery [26].	0/1
	CNXI-preserving ND: 9% (upper), 18% (middle), 18% (lower) [84]; 16% (whole muscle) [96].	2/2	MRND: 27% on completion of surgery [27]; 78% at 6 months post-surgery [26].	0/2
	CNXI-sacrificing ND with no motor input from CP: 100% (upper), 100% (middle), 43% (lower) [84].	1/1	SND: 0% on completion of surgery [27]; 43% at 6 months post-surgery [26].	0/2
	CNXI-sacrificing ND with motor input from CP: 100% (upper), 50% (middle), 50% (lower) [84].	1/1	SND II-IV: 20% at >1 year post-surgery [25].	1/1
			SND II-V: 85% at >1 year post-surgery [25].	1/1
Abnormal sternocleidomastoid muscle EMG	CNXI-preserving ND: 49% [96].	1/1	SND II-IV: 40% at >1 year post-surgery [25].	1/1
			SND II-V: 45% at >1 year post-surgery [25].	1/1
Loss of neck AROM	Mixed cohort: 13% (rotation to non-operated side); 3% (rotation to operated side); 11% (lateral flexion to operated side); 11% (lateral flexion to non-operated side) [29]; 1 to 4% [52].	1/1	-	-
Loss of neck ROM	Mixed cohort: Medium to high limitation on neck rotation: 80% [30].	1/1	Mixed cohort: 34% (flexion); 45% (extension); 38% (lateral flexion to operated side); 34% (lateral flexion to non-operated side); 41% (rotation to operated side); 45% (rotation to non-operated side); all measurements taken 3 to 5 weeks post-surgery [37].	1/1
Neck pain	Mixed cohort: 0 to 45% [31-36].	5/6	Mixed cohort: 70% at 1 day post-surgery; 13% at 1 week post-surgery; 7% at 1 month post-surgery; 3% at 2 months post-surgery [34].	1/1
			ND with preserved cervical root branches: 37% at 18 months post-surgery [28].	0/1
			ND with sacrificed cervical root branches: 73% at 18 months post-surgery [28].	0/1

Loss of sensation at the neck	Mixed cohort: 7 to 86% [29, 30, 33, 36, 52]. RND: 49 to 89% [5, 20]. MRND: 36% [5]. SND: 17% [5].	5/6 2/2 1/1 1/1	ND with preserved CP: 71% at 2 weeks post-surgery; 76% at 1 month post-surgery; 24% at 3 months post-surgery; 41% at 6 months post-surgery [38]. ND with sacrificed CP: 82% at 2 weeks post-surgery; 100% at 1 month post-surgery; 100% at 3 months post-surgery; 100% at 6 months post-surgery [38].	0/1 0/1

[#] The authors of this study use resisted scapular movements to indicate trapezius muscle strength: upper trapezius is tested with scapular elevation; middle trapezius is tested with scapular adduction; and lower trapezius is tested with scapular depression and adduction. The trapezius muscle is not the only muscle that contributes to each of these movements (e.g. levator scapulae contributes to scapular elevation with upper trapezius). The finding that zero patients out of seven with a history of CNXI-sacrificing ND and no motor input from the CP had a loss of scapular elevation strength may be explained by the contribution of levator scapulae to the movement. The results from this study should be interpreted with caution.

* Inclusive of n = 43 surgically treated and n = 57 non-surgically treated (XRT± chemotherapy); figures for surgery only not reported.

^ This study recorded the number of patients who scored above 5 on the Shoulder Disability Questionnaire, not zero.

ND = neck dissection; RND = radical neck dissection; MRND = modified radical neck dissection; SND = selective neck dissection; XRT = radiation therapy; CNXI = accessory nerve; CP = cervical plexus; SCM = sternocleidomastoid; IJV = internal jugular vein; C2-3 = cervical spine nerve roots 2-3; AROM = active range of motion; PROM = passive range of motion; ROM = range of motion; EMG = electromyography; SDQ = Shoulder Disability Questionnaire; UW QOL = University of Washington Quality of Life; DASH = Disabilities of the Arm, Shoulder and Hand.

Table 4: Summary of key results from included studies reporting risk factors (detailed listing of results can be found in the Online Supplementary Material).

Outcome	Risk factors reported as significant with accompanying strength of association (as originally reported in the referenced article)	Risk factors reported as significant but without accompanying strength of association
HRQOL	RND*:coefficient = -22.205; p = 0.006 [39]	Total laryngectomy [69]
	Radioactive iodine: coefficient = -7.182; p = 0.003 [39]	Advanced-stage disease [49]
	Resection of CNXI during ND: coefficient = -20.2; p = 0.0001 [43]	XRT [49]
	T3-4 tumour: coefficient = 6.6; p = 0.04 [43]	Chemotherapy [49]
	>2 years after treatment: coefficient = 8.3; p = 0.02 [43]	CNXI-sacrificing ND* [67]
Self-reported shoulder function (SDQ)	-	Neck dissection [57]
		Cluster: AROM of abduction and flexion at discharge from hospital, non-selective ND and presence of shoulder droop [51]
		SDQ baseline [51]
Composite objective and subjective measure of shoulder function (Constant score)	ND: coefficient = -13.6; p = 0.0007 [41]	Type of ND [50]
	XRT[†]: coefficient = -8.7; p = 0.1245 [41]	
	Patient weight: coefficient = 0.6; p < 0.0001 [41]	
Shoulder pain	SND: coefficient (95% CI) = -9.6 (-19.1, -0.2); p value not listed [42]	Pain at 3 or 12 months[#] [45]
		SND II-IV, SND II-V or MRND ± CNXI preservation [44]

		Removal of cervical rootlets during ND [28] ND [45]
Myofascial pain syndrome	Neck dissection: OR (95% CI) = 3.43 (1.16, 10.17); p = 0.026 [40] Primary tumour site at hypopharynx: OR (95% CI) = 6.35 (1.58, 25.56); p = 0.009 [40]	-
Shoulder droop	-	SND II-V or MRND with CNXI sacrifice [45]
Loss of shoulder strength	-	RND [68]
Neck pain	-	Removal of cervical rootlets during neck dissection [28]

* Risk factor for shoulder domain on UW QOL [39, 67].
† P value is not significant however authors state inclusion of radiation therapy made for the best possible model [41].
# Risk factor for pain at two years post-treatment [45].

ND = neck dissection; RND = radical neck dissection; MRND = modified radical neck dissection; SND = selective neck dissection; CNXI = accessory nerve; AROM = active range of motion; SDQ = Shoulder Disability Questionnaire; UW QOL = University of Washington Quality of Life; OR = odds ratio; CI = confidence interval.

FIGURES

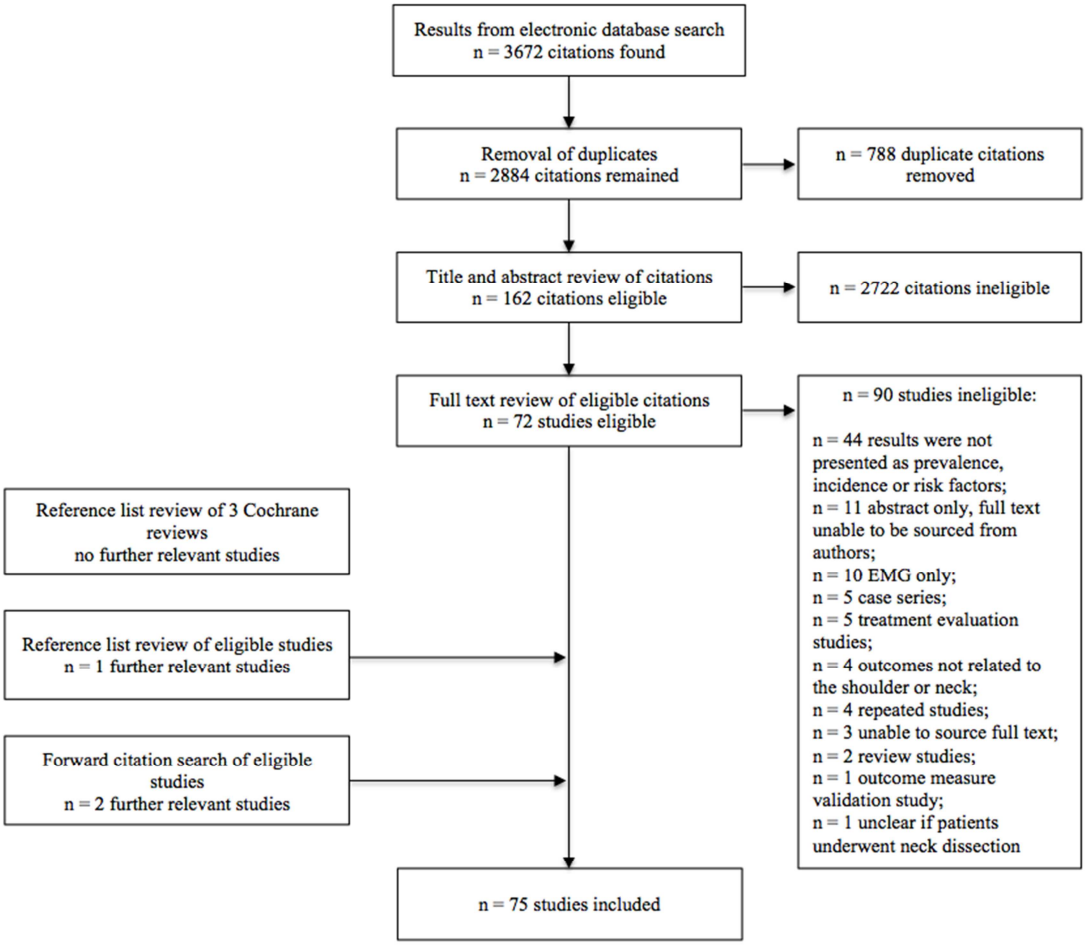

Figure 1: Retrieval and review process.

APPENDICES – ONLINE SUPPLEMENTARY MATERIAL

Appendix One: Key search terms, the method of combination, and information specific to each search source.

Appendix Two: Data extraction form

Appendix Three: Full list of prevalence and incidence results from included studies.

Appendix Four: Full list of risk factor results from included studies.

Appendix Five: These variables were found NOT to be risk factors for various outcomes related to the shoulder and neck.

Appendix One: Key search terms, the method of combination, and information specific to each search source.

Keyword synonyms used to build search strings:

Population: neck dissection
Body region: shoulder, neck

Method of combination within databases:

Pubmed:
#S1: (neck dissection[MeSH Major Topic]) OR "neck dissection"[Text Word]
#S2: (((((((shoulder*[MeSH Terms]) OR shoulder*[Text Word]) OR scapul*[MeSH Terms]) OR scapul*[Text Word]) OR "upper extremity"[MeSH Terms]) OR "upper extremity"[Text Word])) OR "shoulder pain"[MeSH Terms]) OR "shoulder joint"[MeSH Terms]
#S3: ((((((((((((((((((neck[MeSH Terms]) OR "neck pain"[MeSH Terms]) OR "neck injuries"[MeSH Terms]) OR "neck muscles"[MeSH Terms]) OR "cervical plexus"[MeSH Terms]) OR "brachial plexus"[MeSH Terms]) OR "brachial plexus neuropathies"[MeSH Terms]) OR "accessory nerve"[MeSH Terms]) OR "accessory nerve injuries"[MeSH Terms]) OR "accessory nerve disease"[MeSH Terms]) OR cervicodynia[MeSH Terms]) OR cervicalgia[MeSH Terms]) OR brachialgia[MeSH Terms]) OR "brachial neuritis"[MeSH Terms]) OR "cervico brachial neuralgia"[Text Word]) OR "neck pain"[Text Word]) OR "neck injur*"[Text Word]) OR "cervical spine"[Text Word]) OR trapezius[Text Word]) OR "accessory nerve"[Text Word]
#S4: S1 AND S2
#S5: S1 AND S3
#S6: S4 OR S5 → export

Cinahl:
#S1: MH "neck dissection" OR TX "neck dissection"
#S2: TX shoulder* OR TX shoulder injury OR TX scapul* OR TX shoulder syndrome* OR TX upper extremity OR MH shoulder* OR MH scapul* OR MH "upper extremity" OR TX "upper extremity" OR MH "shoulder pain" OR MH "shoulder joint"
#S3: TX neck pain OR TX neck injur* OR TX cervical spine OR TX trapezius OR TX accessory nerve OR TX cervicodynia OR TX cervicalgia OR TX brachialgia OR TX brachial neuritis OR TX brachial neuralgia OR TX cervico brachial neuralgia OR TX monoradicul* OR (MH "Neck") OR (MH "Neck Pain") OR (MH "Neck Injuries") OR (MH "Neck Muscles") OR (MH "Cervical Plexus") OR (MH "Brachial Plexus") OR (MH "Brachial Plexus Neuropathies") OR (MH "Accessory Nerve") OR (MH "Accessory Nerve Diseases") OR ("accessory nerve injuries") OR MH cervicodynia OR MH cervicalgia OR MH brachialgia OR MH brachial neuritis
#S4: S1 AND S2
#S5: S1 AND S3
#S6: S4 OR S5 → export

Embase:
#S1: **'neck dissection':exp OR 'neck dissection':ab,ti**
#S2: **shoulder*:ab,ti OR shoulder AND injury:ab,ti OR scapul*:ab,ti OR shoulder AND syndrome*:ab,ti OR upper AND extremity:ab,ti**
#S3: '**shoulder**'/exp OR '**shoulder girdle**'/exp OR '**shoulder pain**'/exp OR '**shoulder injury**'/exp
#S4: #2 OR #3
#S5: '**neck pain**':ab,ti OR '**neck**'/exp OR **neck** AND **injur***:ab,ti OR '**cervical spine**':ab,ti OR **trapezius**:ab,ti OR '**accessory nerve**':ab,ti OR **cervicodynia**:ab,ti OR **cervicalgia**:ab,ti OR '**brachialgia**':ab,ti OR '**brachial neuritis**':ab,ti OR '**cervico brachial neuralgia**':ab,ti OR **monoradicul***:ab,ti
#S6: '**neck**'/exp OR '**neck pain**'/exp OR '**neck injury**'/exp OR '**neck muscle**'/exp OR '**cervical plexus**'/exp OR '**brachial plexus**'/exp OR '**brachial plexus neuropathy**'/exp OR '**accessory nerve**'/exp OR '**accessory nerve disease**'/exp OR '**accessory nerve injury**'/exp
#S7: #5 OR #6
#S8: #1 AND #4
#S9: #1 AND #7
#S10: #8 OR #9

Cochrane:
#S1: "neck dissection":ti,ab,kw (Word variations have been searched)
#S2: MeSH descriptor: [Neck Dissection] explode all trees
#S3: #1 OR #2

OpenGrey.eu:
#S1: Keyword: neck
#S2: Keyword: shoulder
#S3: neck dissection

NYAM www.nyam.org (http://www.nyam.org/library/):
Keyword search: “neck dissection”
Keyword search: head and neck cancer

Trip:
#S1: “neck dissection” keywords anywhere in text
#S2: shoulder, or scapul*, or "shoulder injury", or "shoulder syndrome", or "upper extremity" keywords anywhere in text
#S3: "neck or pain", or "neck or injury", or "cervical or spine", or trapezius, or "accessory or nerve", or cervicodynia, or cervicalgia, or brachialgia, or "brachial or neuritis", or "cervico or brachial or neuralgia", or monoradicul*) keywords anywhere in text
#S4: (#1 AND #2) OR (#1 AND #3)

Appendix Two: Data extraction form

Reviewer: _____
Date: _____
Study Author: _____
Year: _____
Title: _____
Journal: _____
METHODS:
Study design: Case-control Retrospective cohort
Cross-sectional
Prospective cohort Other:_____
Total number subjects: _____
Group labels and number of participants in study:
_____
Setting: _____
Enrolment: Consecutive Non consecutive
Time of assessment relative to surgery: _____
Number of withdrawals: _____
Reasons for withdrawals: _____
Primary outcome measure (and equipment used): _____
Secondary outcome measures (and equipment used): _____
_____
Profession and experience of assessor: _____
Do the results report: Prevalence Incidence Associations Risk factors
Summarise the results: _____
Do the authors list any limitations?: _____

Appendix Three: Full list of prevalence and incidence results from included studies.

Outcome	Results
Loss of shoulder abduction AROM – prevalence	Mixed cohorts: Difference in shoulder abduction AROM of <40˚: 88/111 (79%) [23]. Difference between operated and non-operated arms present in 21/52 (40%) [29]. Elevation of the arm above the horizontal: good 9/54 (17%), slightly reduced 23/54 (43%), poor 22/54 (41%) [82]; 58/60 (97%) [32]. Unilateral RND: 17/18 (94%) [18]; 81/89 (92%) [20]. Bilateral RND: 89/89 (100%) [20]. MRND: 8/35 (23%) [18].
Loss of shoulder flexion AROM - prevalence	Unilateral RND: 48/89 (54%) [20].
Loss of shoulder abduction AROM – incidence	Mixed cohort: 12/12 (100%) (with 2kg weight: 12/12 (100%)) [24]. SND II-IV: 160-180° 1/20 (5%) [25]. SND II-V: 160-180° 4/20 (20%), 140-160° 1/20 (5%) [25].
Loss of shoulder abduction PROM – prevalence	Mixed cohort: 10/11 (91%) (9 limited by pain) [80]; 150˚ or less: 34/60 (57%) [32]. RND: 5/10 (50%) [54]. CNXI-preserving ND: 0/10 (0%) [54].
Loss of shoulder flexion PROM – prevalence	Mixed cohort: 8/11 (73%) (8 limited by pain) [80].
Loss of shoulder abduction PROM – incidence	Mixed cohort: 11/12 (92%) [24].
Loss of shoulder abduction ROM (not defined as active or passive) – prevalence	RND: 21/24 (87%) [2]. MRND: 11/18 (61%) [2]; 8/21 (38%) [53]; 4/19 (21%) [17]. SND: 4/24 (17%) [2]. Conservative ND: 6/8 (75%) [53].
Loss of shoulder ROM (not defined as active or passive) – incidence	Mixed cohort: 27/29 (93%) lost abduction; 29/29 (100%) lost flexion; 3/39 (10%) lost extension; 15/29 (52%) lost horizontal abduction; 10/29 (34%) lost horizontal adduction; 2/29 (7%) lost external rotation; 8/29 (28%) lost internal rotation [37]. RND: 2/5 (20%) [26]; 9/15 (60%) [54].. MRND: 2/9 (22%) [26]; 1/15 (7%) [54]. SND: 0/7 (0%) [26]
Loss of general shoulder strength – prevalence	Mixed cohort: 11% [22]. SND: moderately impaired 2/29 (7%), severely impaired 2/29 (7%) [85]. SNB: 0/33 (0%) [85].

Outcome	Results
Loss of trapezius muscle strength – prevalence	CNXI-preserving ND: 0/11 (0%) (upper trapezius)[#]; 6/11 (55%) (middle trapezius)[#]; 7/11 (64%) (lower trapezius)[#] [84]; 5/44 (11%) [96]. CNXI-sacrificing ND and no motor input from CP: 0/7 (0%) (upper trapezius)[#]; 7/7 (100%) (middle trapezius)[#]; 7/7 (100%) (lower trapezius)[#] [84]. CNXI-sacrificing ND and motor input is present from CP: 0/2 (0%) (upper trapezius)[#]; 2/2 (100%) (middle trapezius)[#]; 2/2 (100%) (lower trapezius)[#] [84]. RND: 10/10 (100%) [96].
Loss of sternocleidomastoid muscle strength - prevalence	CNXI-preserving ND: 2/41 (5%) [96].
Loss of general shoulder strength – incidence	RND: 4/5 (80%) [26]. MRND 4/9 (44%) [26]. SND 0/7 (0%) [26].
Loss of trapezius muscle strength – incidence	SND II-IV: 0/20 (0%) [25]. SND II-V: 4/20 (20%) [25].
Shoulder droop – prevalence	Mixed cohort: 9/43 (31%) [57]; 34/54 (63%) [82]; 1cm 32/60 (53%), 2cm 9/60 (15%), 3cm 9/60 (15%), 4cm 9/60 (15%), 5cm 1/60 (2%) [32]. RND: 4/9 (44%) [5]; 83/133 (62%) [4]; 5/5 (100%) [23]; 47/89 (53%) [20]; 8/10 (80%) [21]. Bilateral RND: 5/11 (46%) [20]. CNXI-preserving ND: 0/10 (0%) [21]. MRND: 3/11 (27%) [5]; 0/151 (0%) [4]; 13/43 (30%) [23]. SND: 0/23 (0%) [5]. SND II-V: 9/16 (56%) [23]. SND I-III: 6/48 (13%) [23].
Shoulder droop – incidence	Mixed cohort: at discharge from hospital 57%, at 4 months post-surgery 52% [51]; Shoulder drop with muscle atrophy: 3/30 (10%) [55]. Shoulder drop with muscle atrophy and wing scapula: 1/30 (3.33%) [55]. RND: 30/35 (86%) [56]. MRND: 9/36 (35%) [56]. MRND with sacrifice of SCM and IJV: 14/28 (50%) [56]. SND II-IV: 1/20 (5%) [25]. SND II-V: 6/20 (30%) [25].
Atrophy of the upper trapezius muscle – prevalence	Mixed cohort: 31/54 (57%) [82]; ND without XRT 6/128 (5%); ND with XRT 2/72 (3%) [52]. RND: 5/5 (100%) [23]. MRND: 12/43 (28%) [23]. SND II-V: 9/16 (56%) [23].

Outcome	Results
	SND I-III: 3/48 (6%) [23].
Atrophy of the upper trapezius muscle – incidence	Mixed cohort: 4/30 (13%) [55].
Subjective shoulder stiffness – prevalence	Mixed cohort: 35/43 (81%) [57]. RND: 6/10 (60%) [21]. CNXI-preserving ND: 0/10 (0%) [21]. SND I-IV: moderate symptoms 3% [22]. SND II-V/MRND: moderate symptoms 6%, severe symptoms 2% [22].
Shoulder pain – prevalence	Mixed cohort: 18/29 (62%) [36]; 39/122 (35%) [23]; 5/20 (25%) [31]; 18/43 (42%) [57]; 3/52 (6%) [29]; Pain occasionally 22/54 (41%), disabling pain 17/54 (32%) [82]; Pain at rest: shoulder 0/72 (0%), arm 25/72 (35%); Pain on movement: shoulder 34/72 (47%), arm 33/72 (46%) [32]; Mild 23/46 (50%), moderate 8/46 (17%), severe 6/46 (13%) [90]; Mild pain 8/29 (28%), moderate pain 9/29 (31%), severe pain 4/29 (14%), very severe pain 1/29 (3%) [91]; ND only 34/128 (27%), ND + XRT 5/72 (7%) [52]. RND: minimum pain intensity 4%, moderate 10%, severe 50% [19]; 12/12 (100%) [3]; No pain 3/24 (13%), light 5/24 (21%), moderate 6/24 (25%), severe 10/24 (42%) [2]; 35/133 (26%) [4]; 5/9 (56%) [5]; 7/9 (78%) [17]; At rest 8/18 (44%), with movement 12/18 (67%) [18]; 42/89 (47%) [20]; 1/10 (10%) (ache 4/10 (40%)) [21]. MRND (CNXI preserved): minimum 48%, moderate 30%, severe 22% [19]; 14/23 (61%) [3]; No pain 8/18 (44%), light 6/18 (33%), moderate 4/18 (22%) [2]; 16/151 (11%) [4]; 4/11 (36%) [5]; 5/19 (26%) [17]; At rest 5/35 (14%), with movement 6/35 (17%) [18]; 0/10 (0%) (ache 0/10 (0%)) [21]. MRND (CNXI and C2-3 preserved): minimum 80%, severe 20% [19]. SND: no pain 18/24 (75%), light 5/18 (21%), moderate 1/24 (4%) [2]; 2/23 (9%) [5]. SND I-IV: moderate pain 7% [22]. SND II-V/MRND: moderate pain 21%, severe pain 4% [22].
Shoulder pain – incidence	Mixed cohort: at discharge from hospital 55%, at 4 months post-operatively 48% [51]; Dull continuous shoulder pain: 8/12 (67%) (3/8 (38%) spontaneous pain, 5/8 (63%) pain with movement) [24]; 89/128 (70%) [42]. ND with preserved cervical root branches: 9/24 (14%) [28]. ND with sacrificed cervical root branches: 20/29 (69%) [28]. ND with CP preserved: 2 weeks post-surgery mild pain 11/17 (65%), moderate pain 5/17 (29%), severe pain 1/17 (6%); 1 month post-surgery mild pain 11/17 (65%), moderate pain 5/17 (29%), severe pain 1/19 (6%); 3 months post-surgery mild pain 13/17 (76%), moderate pain 4/17 (24%); 6 months post-surgery mild pain 14/17 (82%), moderate pain 3/17 (18%) [38]. ND with CP sacrificed: 2 weeks post-surgery mild pain 12/17 (70%), moderate pain 5/17 (30%); 1 month post-surgery mild pain 11/17 (65%), moderate pain 6/17 (35%); 3 months post-surgery mild pain 12/17 (71%), moderate pain 5/17 (29%); 6 months post-surgery mild pain 13/17 (76%), moderate pain 4/17 (24%) [38]. SND: 2/7 (29%) [26].

Outcome	Results
	MRND: 5/9 (56%) [26]; 6/15 (40%) [54]; 11/36 (31%) [56]. MRND with preservation of CNXI and sacrifice of SCM and IJV: 10/28 (36%) [56]. RND: 5/5 (100%) [26]; 2/15 (13%) [54]; 21/35 (60%) [56]; 2 weeks post-surgery 17%, 6 months post-surgery 17% [70]. RND/MRND with preservation of CNXI and sacrifice of SCM and IJV: 2 weeks post-surgery 13%, 6 months post-surgery 31% [70].
Shoulder Disability Questionnaire (SDQ) – prevalence	Mixed cohort: SDQ > 0 54/100 (54%) (inclusive of n = 43 surgically treated and n = 57 non-surgically treated (XRT± chemotherapy); figures for surgery only not reported) [57]. MRND: SDQ > 0 17/51 (33%) [9]. SND II-V: SDQ > 0 14/21 (67%) [9]. SND I-III: SDQ > 0 13/65 (20%) [9]. CNXI-sacrificing ND: SDQ > 5 9/10 (90%) [76]. CNXI-preserving ND: SDQ > 5 3/32 (10%) [76].
Pain domain of the University of Washington Quality of Life (UW QOL) questionnaire – prevalence	CNXI-sacrificing ND: moderate pain requiring analgesia 6/107 (6%), severe pain controlled by narcotics 33/107 (30%), severe pain not controlled by medication 68/107 (64%) [81]. CNXI-preserving ND: moderate pain requiring analgesia 2/84 (2%), severe pain controlled by narcotics 15/84 (18%), severe pain not controlled by medication 67/84 (80%) [81].
Shoulder domain of the University of Washington Quality of Life (UW QOL) questionnaire – prevalence	CNXI-sacrificing ND: no problem 1/107 (1%), shoulder stiffness but no effect on activity or strength 23/107 (22%), pain or weakness in the shoulder causing the participant to change their work 60/107 (56%), cannot work due to shoulder problems 23/107 (21%) [81]. CNXI-preserving ND: no problem 0/84 (0%), shoulder stiffness but no effect on activity or strength 9/84 (11%), pain or weakness in the shoulder causing the participant to change their work 29/84 (34%), cannot work due to shoulder problems 46/84 (55%) [81].
Modified Constant score – prevalence	SND: Total score: mild 32%, moderate 6%, severe dysfunction 12%. Subjective sub-score: mild 8%, moderate 12%, severe 24%. Objective sub-score: mild 40%, moderate 4%, severe 12% [95].
Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire severity of upper limb dysfunction – prevalence	Mixed cohort: none 23%, mild 54%, moderate 15%, severe 8% [72]. SND I-III: none 14%, mild 60%, moderate 17%, severe 9% [72]. Extended SND I-III: none 33%, mild 50%, moderate 17%, severe 0% [72]. SND II-IV: none 45%, mild 45%, moderate 9%, severe 0% [72].
Shoulder “dysfunction” – prevalence	Mixed cohort: 7% [93]; None 28%, slight 41%, severe 31% [82]; 37/133 (26%) unilateral and 20/56 (36%) bilateral [52]. RND: 6/9 (67%) [5]; 12/12 (100%) [73]; 36/36 (100%) [16]; 10/11 (91%) [89]; 4/4 (100%) [92]. MRND: 4/11 (36%) [5]; 8/12 (67%) [73]; 38/64 (59%) [89]. SND: 3/23 (13%) [5]; 7/17 (41%) [89]. MRND with preservation of CNXI and sacrifice of SCM and IJV: 26/55 (47%) [16]; 6/96 (6%) [92]. MRND with preservation of SCM and IJV and sacrifice of CNXI: 5/5 (100%) [92].

Outcome	Results
Shoulder "dysfunction" – incidence	RND: 5/5 (100%) [23]. MRND: 16/78 (20%) [71]; 12/43 (28%) [23]; 3/11 (27%) [27]. SND: 1/11 (9%) [27]. SND I-III: 2/24 (8%) [71]; 3/48 (6%) [23]. SND II-V: 9/16 (56%) [23]; 3/20 (15%) [25]. SND II-IV: 1/20 (5%) [25].
Accessory nerve palsy – prevalence	RND: 133/133 (100%) [4]; 18/18 (100%) [18]. MRND: 16/151 (11%) [4]. MRND with preservation of CNXI and sacrifice of SCM and IJV: 15/35 (43%) [18].
Accessory nerve palsy/dysfunction – incidence	Mixed cohort: 27% [83]; 12/714 (2%) [88]. Thyroidectomy, excision of pretracheal and paratracheal nodes, and I131 ablation: 2/82 (2%) [79]. Thyroidectomy and excision of nodes in tracheoesophageal groove (extensive ND): 13/81 (17%) [79]. RND: 21/413 (5.1%) (18/21 had CNXI sacrificed; 3/21 had CNXI preserved) [77]; 1 month post-surgery minimal problem 10/39 (26%), moderate problem 15/39 (39%), maximum problem 9/39 (23%), loss of function 4/39 (10%). 1 year post-surgery minimal problem 16/39 (41%), moderate problem 10/39 (6%), maximum problem 7/39 (18%), loss of function 3/39 (8%) [6]. SND I-III: 1 month post-surgery minimal problem 21/41 (51%), moderate problem 6/41 (15%), maximum problem 2/41 (5%); 1 year post-surgery: minimal problem 13/41 (32%), moderate problem 2/41 (5%), maximum problem 1/41 (2%) [6]. FND: 1 month post-surgery minimal problem 19/47 (40%), moderate problem 14/47 (30%), maximum problem 6/47 (13%); 1 year post-surgery minimal problem 20/47 (43%), moderate problem 12/47 (26%), maximum problem 4/47 (9%) [6]. Conservative ND: 2/32 (6%) [78]. Extensive ND: 13/51 (25%) [78]. MRND/RND: permanent lesion 9/668 (1%), transient lesion 3/668 (0.3%) [87].
Cervical plexus lesion – incidence	MRND/RND: 2/668 (0.3%) [87].
Abnormal trapezius muscle EMG – prevalence	Mixed cohort: 41/54 (76%) (upper), 24/54 (44%) (middle), 22/54 (41%) (lower) [82]. RND: 10/10 (100%) [96]. CNXI-preserving ND: 1/11 (9%) (upper), 2/11 (18%) (middle), 2/11 (18%) (lower) [84]; 7/44 (16%) [96]. CNXI-sacrificing ND with no motor input from CP: 7/7 (100%) (upper), 7/7 (100%) (middle), 3/7 (43%) (lower) [84]. CNXI-sacrificing ND with motor input from CP: 0/2 (100%) (upper), 1/2 (50%) (middle), 1/2 (50%) (lower) [84].
Abnormal sternocleidomastoid muscle EMG - prevalence	CNXI-preserving ND: 20/41 (49%) [96].

Outcome	Results
Abnormal trapezius muscle EMG – incidence	Mixed cohort: 1 month post-surgery 11/29 (40%), 18 months post-surgery 25/29 (85%) [86]. RND: 5/5 (100%) [26]. MRND: 7/9 (78%) [26]; 3/11 (27%) [27]. SND: 3/7 (43%) [26]; 0/11 (0%) [27]. SND II-IV: 4/20 (20%) [25]. SND II-V: 17/20 (85%) [25].
Abnormal sternocleidomastoid muscle EMG - incidence	SND II-IV: 8/20 (40%) [25]. SND II-V: 9/20 (45%) [25].
Neuropathic symptoms arm – prevalence	Mixed cohort: Pain/numbness in arm 7/20 (35%); neuropathic pain 1/20 (5%) [31].
Deformity of clavicle – prevalence	RND: 9/9 (100%) [5]. MRND: 4/11 (36%) [5]. SND: 2/23 (9%) [5].
Subluxation of the sternoclavicular joint - prevalence	Mixed cohort: 19/54 (35%) [82]; (47%) [32].
Sternoclavicular joint pain – prevalence	Mixed cohort: 24/153 (16%) [35].
Sternoclavicular joint pain – incidence	ND with preserved cervical root branches: 0/24 (0%) [28]. ND with sacrificed cervical root branches: 0/29 (0%) [28].
Acromioclavicular joint pain – prevalence	Mixed cohort: 13/29 (45%) [36]; 37/153 (24%) [35].
Acromioclavicular joint pain – incidence	ND with preserved cervical root branches: 1/24 (4%) [28]. ND with sacrificed cervical root branches: 1/29 (3%) [28].
Loss of neck AROM – prevalence	Mixed cohort: Rotation restriction of up to 30° towards the non-operated side 5/38 (13%), rotation restriction of 15° towards the operated side 1/32 (3%); Lateral flexion 10˚ more towards the operated side 4/38 (11%), 10˚ more away from the operated side 4/38 (11%) [29]; ND only 1/128 (1%), ND + XRT 3/72 (4%) [52].
Loss of neck ROM – prevalence	Mixed cohort: Medium to high limitation on neck rotation: 44/55 (80%) [30].

Outcome	Results
Loss of neck ROM (not defined as active or passive) – incidence	Mixed cohort: Loss of neck flexion 10/29 (34%). Loss of neck extension 13/29 (45%). Loss of lateral flexion to operated side 11/29 (38%). Loss of lateral flexion to non-operated side 10/29 (34%). Loss of rotation to operated side 12/29 (41%). Loss of rotation to non-operated side 13/29 (45%) [37].
Neck pain – prevalence	Mixed cohort: no neck pain in the last 7 days 16/29 (55%), reported mild to moderate neck pain in the last 7 days 13/29 (45%) [36]; 51/153 (33%) [35]; 43% [33]; 8/20 (40%) [31]; 21/72 (29%) [32]; 0/31 (0%) >2 years post-surgery, 4/27 (15%) 6 to 24 months post-surgery [34].
Neck pain – incidence	ND with preserved cervical root branches: 9/24 (37%) [28]. ND with sacrificed cervical root branches: 21/29 (73%) [28]. Mixed cohort: 21/30 (70%) at day 1, 4/30 (13%) at 1 week, 2/30 (7%) at 1 month, 1/30 (3%) at 2 months post-surgery [34].
Loss of sensation at the neck – prevalence	Mixed cohort: 25/29 (86%) [36]; 57% [33]; 34/52 (65%) [29]; 72% [30]; 9/128 (7%) [52]. RND: 8/9 (89%) [5]; 44/89 (49%) [20]. MRND: 4/11 (36%) [5]. SND: 4/23 (17%) [5].
Loss of sensation at the neck – incidence	ND with preserved CP: Pre-surgery 0/17 (0%); 2 weeks post-surgery 12/17 (71%); 1 month post-surgery: 13/17 (76%); 3 months post-surgery 4/17 (24%); 6 months post-surgery 7/17 (41%) [38]. ND with sacrificed CP: Pre-surgery 0/17 (0%); 2 weeks post-surgery 14/17 (82%); 1 month post-surgery 17/17 (100%); 3 months post-surgery 17/17 (100%); 6 months post-surgery: 17/17 (100%) [38]. RND: Occipitalis minor at 2 weeks post-surgery: warm 31% cold 44% sharp 56% blunt 50%; 6 months: warm 62.5% cold 25% sharp 62.5% blunt 75%. C2 at 2 weeks post-surgery: warm 63% cold 69% sharp 94% blunt 88%; 6 months: warm 75% cold 69% sharp 88% blunt 94%. C3 at 2 weeks post-surgery: warm 44% cold 44% sharp 63% blunt 63%; 6 months: warm 56% cold 38% sharp 56% blunt 56%. C4 at 2 weeks: warm 63% cold 69% sharp 56% blunt 69%; 6 months: warm 81% cold 69% sharp 75% blunt 88% [70]. RND/MRND with preservation of CNXI and sacrifice of SCM and IJV: Occipitalis minor at 2 weeks post-surgery: warm 8% cold 4% sharp 13% blunt 17%; 6 months: warm 0% cold 0% sharp 0% blunt 0%. C2 at 2 weeks post-surgery: warm 46% cold 58% sharp 88% blunt 88%; 6 months: warm 38% cold 33% sharp 46% blunt 50%. C3 at 2 weeks post-surgery: warm 21% cold 17% sharp 8% blunt 8%; 6 months: warm 13% cold 8% sharp 0% blunt 4%. C4 at 2 weeks post-surgery: warm 42% cold 38% 42% 38%; 6 months: warm 21% cold 13% sharp 17% blunt 8% [70].
Allodynia – prevalence	Mixed cohort: 2/29 (7%) [36]; 20/153 (39%) [35].
Allodynia – incidence	ND with preserved cervical root branches: 2/24 (8%) [28]. ND with sacrificed cervical root branches: 9/29 (31%) [28].
Hyperpathia – prevalence	Mixed cohort: 49/153 (32%) [35].

Outcome	Results
Hyperpathia – incidence	Mixed cohort: C2-4 14/72 (19%), C3-C5 18/72 (25%), C3-C4 72/72 (100%) [32]; 53/128 (41%) [52]. ND with preserved cervical root branches: 5/24 (21%) [28]. ND with sacrificed cervical root branches: 16/29 (55%) [28]. RND: 6/89 (7%) [20].
Lymphoedema – prevalence	Mixed cohort: 10/52 (19%) [29]; 16/55 (29%) [30]; 27/60 (45%) [32]. RND: 4/9 (44%) [5]. MRND: 3/11 (27%) [5]. SND: 1/23 (4%) [5].
Lymphoedema – incidence	MRND: 12/24 (26%) [71]. SND: I-III 1/78 (7%) [71].
Concerns with scar and cosmesis – prevalence	Mixed cohort: 27% [33]; 1/52 (2%) [29]; 17/55 (31%) [30]; 15/128 (12%) [52]. RND: 6/9 (67%) [5]; 9/89 (10%) [20]. MRND: 8/11 (73%) [5]. SND: 4/23 (17%) [5].
Subjective reports of neck tightness/restriction – prevalence	Mixed cohort: 66% (35%) [33]; 2/52 (4%) [29].
Neck deformity – incidence	RND: 14/15 (93%) [54]. MRND: 1/15 (7%) [54].
Combination of outcomes reported as one result – incidence	Subjective report of shoulder pain, decrease in shoulder muscle power and shoulder ROM and numbness in neck: RND 1/51 (2%), SND 0/18 [75]. Nerve dysfunction or pain: 19% [93]. Patients with paresis who reported daily shoulder pain and/or were aware of shoulder dysfunction: 22/33 (67%) [18]. At each of the four time points (1 month, 6 months, 12 months, 18 months post-operatively), 21/29 (71%) to 24/29 (83%) of patients had significant PROM limitations, pain, weakness in flexion external rotation, and internal rotation of the shoulder [86].
Subjective reports relating to the shoulder – prevalence	Subjective report of functional restrictions: 10/11 (91%) [80]. Subjective report of surgery causing shoulder weakness: 10/11 (91%) [80]. Subjective report of improvement in shoulder strength since surgery: 9/11 (82%) [80]. Subjective reports of limited shoulder abduction AROM in supine: 10/11 (91%) [80]. Subjective reports of limited shoulder abduction ROM in sitting due to weakness: 11/11 (100%) [80]. Answers from the questionnaire for patients after unilateral surgery (bilateral surgery patient data not listed): Activity disability: RND minimum 30%, moderate 20%, severe 50%; MRND (CNXI preserved) minimum 52%, moderate 22%, severe 26%; MRND (CNXI and C2-3 preserved) minimum 80%, severe 20% [19]. Subjective report of limitation of daily activities: RND 35%; MRND/SND 8% [33].

Outcome	Results
	Subjective report of shoulder discomfort (with figure for prevalence of interference with daily life): Whole cohort 53% (33%) [33]. Subjective report of restriction to shoulder and arm movement: slight or moderate restriction 7/52 (14%), no restriction 52/52 (86%) [29]. Subjective report of restriction to leisure time and everyday activities: slight to moderate restriction 6/52 (12%), no restriction 46/52 (89%) [29]. RND group: 8% no post-surgery performance difficulty. MRND/CND group: 9% high scores on post-surgery performance disability rating. XRT group: 12% noticed change in performance [3]. Subjective report of difference in movement between operated and non-operated shoulders: MRND with preservation of CNXI and sacrifice of SCM and IJV yes 6/19 (32%), no 13/19 (68%) [17]. Subjective report of surgery being the cause of shoulder weakness: 10/12 (83%) (8/10 (80%) report shoulder strength has returned since surgery) [24]. Subjective report of limited shoulder movement: RND 7/18 (39%), MRND with preservation of CNXI and sacrifice of SCM and IJV 5/35 (14%) [18]. Subjective report of handicap in social activities: RND 8/18 (44%), MRND with preservation of CNXI and sacrifice of SCM and IJV 5/35 (14%) [18]. Subjective shoulder weakness: unilateral RND 5/89 (6%), no figure reported for bilateral RND [20]. Subjective loss of shoulder AROM: unilateral RND 60/89 (67%), bilateral RND 8/11 (73%) [20]. Employment figures for the whole cohort: retired prior to surgery 9/100 (9%), could return to previous employment 79/100 (79%), sought alternative employment 9/100 (9%), totally incapacitated 3/100 (3%) [20]. Able to resume former occupation after surgery: 19/54 (35%). Employed with limitations: 14/54 (26%) (5 in a new job). Disabled: 8/54 (15%). Already retired: 13/54 (24%). No personal changes 24/54 (44%). Problems washing/dressing, give up hobbies: 18/54 (33%). Social life severely restricted: 12/54 (22%) [82]. "Shoulder symptoms": MRND with preservation of CNXI and sacrifice of SCM and IJV none 38/55 (69%), mild 13/55 (24%), moderate 3/55 (5%), severe 1/55 (2%); RND none 18/36 (50%), mild 6/36 (17%), moderate 5/36 (14%), severe 7/36 (19%) [16]. Function: Brushing hair: no problems 33/60 (55%), limited 21/60 (35%), unable 6/60 (10%). Get dressed: no problems 49/60 (82%), limited 10/60 (17%), unable 1/60 (2%). Hand Behind Back: no problems 33/60 (55%), limited 13/60 (22%), unable 4/60 (7%) [32]. Patients who were employed prior to RND who then ceased working after RND because of their shoulder: 11/24 (46%) [90]. Mobility complaints: SND I-IV no symptoms 85%, moderate 15%; SND II-V/MRND no symptoms 76%, moderate 19%, severe 5%. Weakness: SND I-IV no symptoms 93%, moderate 7%. SND II-V/MRND no symptoms 80%, moderate 17%, severe 3% [22]. Subjective report of shoulder movement limitation: ND only 29/128 (23%), ND + XRT 20/72 (28%) [52].
Subjective reports relating to the shoulder – incidence	Difficulties with washing: 54/177 (31%). Difficulties with dressing: 52/177 (52%) [42]. Patients who were symptomatic: 1 month 89%, 6 months 93%, 12 months 82%, 18 months 90% [86].

[#]The authors of this study use resisted scapular movements to indicate trapezius muscle strength: upper trapezius is tested with scapular elevation; middle trapezius is tested with scapular adduction; and lower trapezius is tested with scapular depression and adduction. The trapezius muscle is not the only muscle that contributes to each of these movements (e.g. levator scapulae contributes to scapular elevation with upper trapezius). The finding that zero patients out of seven with a history of CNXI-sacrificing ND and no motor input from the CP had a loss of scapular elevation strength may be explained by the contribution of levator scapulae to the movement. The results from this study should be interpreted with caution.

ND = neck dissection; RND = radical neck dissection; MRND = modified radical neck dissection; SND = selective neck dissection; FND = functional neck dissection; CNXI = accessory nerve; CP = cervical plexus; XRT = radiation therapy; AROM = active range of motion; PROM = passive range of motion; ROM = range of motion; EMG = electromyography; SDQ = Shoulder Disability Questionnaire (shoulder function; range 0 = best possible response to 100 = worst possible response); UW QOL = University of Washington Quality of Life (quality of life; range 0 = worst possible response to 100 = best possible response); DASH = Disabilities of the Arm, Shoulder and Hand (arm, shoulder and hand function; range 0 = best possible response to 100 = worst possible response); Modified Constant score = shoulder function (range 0 = worst possible response to 100 = best possible response);

Appendix Four: Full list of risk factor results from included studies.

Risk factor	Associated outcome	Coefficient (coeff or OR) and p value (if available) (as originally reported in the referenced article)	Explanation of association
ND	Head and neck or shoulder and arm pain at 2 years post-treatment [45]	p = 0.01	Undergoing ND is a risk factor for increased head and neck or shoulder and arm pain at 2 years post-treatment
	Neck stiffness [44]	p < 0.001	Undergoing ND is a risk factor for neck stiffness post-surgery
	Neck constriction [44]	p = 0. 01	Undergoing ND is a risk factor for neck constriction post-surgery
	Neck appearance [44]	p = 0. 001	Undergoing ND is a risk factor for poor neck appearance post-surgery
	Myofascial pain syndrome [40]	p = 0.016	Undergoing ND is a risk factor for experiencing myofascial pain syndrome post-surgery
	SDQ [57]	p < 0.01	Reporting a score above zero on the SDQ (i.e. reporting pre-existing shoulder dysfunction) is a risk factor for a higher score on the same outcome post-surgery (i.e. worse shoulder function)
Level V dissection	Neck pain [28]	p < 0.001	Inclusion of level V in the ND field is a risk factor for increased neck pain post-surgery
	Shoulder pain [36]	r_{pbs} = 0.46; p ≤0.05	Inclusion of level V in the ND field is a risk factor for increased shoulder pain post-surgery
SND II-VI and SND II-IV	Shoulder sub-score of the University of Washington Quality of Life (Portuguese version) questionnaire [39]	coeff = -22.205; p = 0.006	Undergoing SND II-VI or SND II-IV is a risk factor for a lower shoulder sub-score on the University of Washington Quality of Life questionnaire (i.e. worse quality of life)
SND II-IV	Shoulder or neck pain [44]	p = 0.001	Undergoing SND II-IV is a risk factor for worse shoulder or neck pain post-surgery
	Neck numbness [44]	p = 0.001	Undergoing SND II-IV is a risk factor for worse neck numbness post-surgery
SND II-V	Shoulder or neck pain [44]	p = 0.001	Undergoing SND II-V is a risk factor for worse shoulder or neck pain post-surgery

Risk factor	Associated outcome	Coefficient (coeff or OR) and p value (if available) (as originally reported in the referenced article)	Explanation of association
	Neck numbness [44]	p = 0.001	Undergoing SND II-V is a risk factor for worse neck numbness post-surgery
	Shoulder drop (if CNXI is sacrificed) [44]	p < 0.001	Undergoing SND II-V with CNXI sacrifice is a risk factor for the presence of a shoulder drop post-surgery
	Reach hand for above object (if CNXI is sacrificed) [44]	p = 0.02	Undergoing SND II-V with CNXI sacrifice is a risk factor for being unable to reach one's hand for an object above one's head post-surgery
MRND	Constant Shoulder Score [41]	p = 0.0007	Undergoing MRND (as opposed to SND) is a risk factor for a lower scores on the Constant Shoulder Score (i.e. worse shoulder function)
	NDII [49]	p = 0.005	Undergoing MRND (as opposed to SND) is a risk factor for a lower score on the NDII (i.e. worse quality of life)
	Shoulder or neck pain [44]	p = 0.001	Undergoing MRND is a risk factor for worse shoulder or neck pain post-surgery
	Neck numbness [44]	p = 0.001	Undergoing MRND is a risk factor for worse neck numbness post-surgery
RND	Shoulder or neck pain [44]	p = 0.001	Undergoing RND is a risk factor for worse shoulder or neck pain post-surgery
	Neck numbness [44]	p = 0.001	Undergoing RND is a risk factor for worse neck numbness post-surgery
	Shoulder drop [44]	p < 0.001	Undergoing RNDV is a risk factor for the presence of a shoulder drop post-surgery
	Reach hand for above object [44]	p = 0.02	Undergoing RND is a risk factor for being unable to reach one's hand for an object above one's head post-surgery
	Constant Shoulder Score [50]	p < 0.0005	Undergoing RND (as opposed to SND or MRND) is a risk factor for a lower scores on the Constant Shoulder Score (i.e. worse shoulder function)
	Shoulder range of motion (not specified as active or passive) [68]	Shoulder flexion p < 0.001 Shoulder abduction	Undergoing RND (as opposed to SND or MRND) is a risk factor for loss of shoulder flexion and abduction range of motion post-surgery

Risk factor	Associated outcome	Coefficient (coeff or OR) and p value (if available) (as originally reported in the referenced article)	Explanation of association
		p < 0.001	
	Shoulder strength [68]	Shoulder elevation p < 0.01 Shoulder abduction p < 0.01	Undergoing RND (as opposed to SND or MRND) is a risk factor for loss of shoulder elevation and abduction strength post-surgery
MRND or RND	Shoulder pain [42]	coeff (95% CI) = -9.6 (-19.1, -0.2); p value not listed	Undergoing MRND or RND is a risk factor for increased shoulder pain post-surgery
	Shoulder abduction range of motion (not specified as active or passive) [42]	coeff (95% CI) = 55.0 (35.0, 75.1); p value not listed	Undergoing MRND or RND is a risk factor for loss of shoulder abduction range of motion post-surgery
CNXI-sacrificing ND	Shoulder range of motion (not specified as active or passive) [67]	Shoulder flexion p = 0.02 Shoulder abduction p = 0.002	Undergoing a CNXI-sacrificing ND (as opposed to CNXI-preserving ND) is a risk factor for reduced shoulder flexion and abduction range of motion
	Restriction to work [44]	p = 0.006	Undergoing ND that involves sacrifice of one or both CNXI (in the case of bilateral ND) is a risk factor for being restricted in one's ability to work post-surgery
	Restriction to leisure [44]	p = 0.04	Undergoing ND that involves sacrifice of one or both CNXI (in the case of bilateral ND) is a risk factor for being restricted in leisure participation post-surgery
	Pain score within the Head and Neck Quality of Life questionnaire [43]	p = 0.0001	Undergoing CNXI-sacrificing ND is a risk factor for lower Head and Neck Quality of Life scores (i.e. worse quality of life)
	Single shoulder or neck pain item within the HNQOL questionnaire [43]	p = 0.02	Undergoing CNXI-sacrificing ND is a risk factor for lower HNQOL scores (i.e. worse quality of life)
Sternocleidomastoid-sacrificing ND	Restriction to dressing [44]	p = 0.046	Undergoing bilateral ND involving sacrifice of both sternocleidomastoid muscles is a risk factor for being restricted in one's ability to dress oneself post-surgery

Risk factor	Associated outcome	Coefficient (coeff or OR) and p value (if available) (as originally reported in the referenced article)	Explanation of association
	Restriction to work [44]	p = 0.006	Undergoing bilateral ND involving sacrifice of both sternocleidomastoid muscles is a risk factor for being restricted in one's ability to work post-surgery
	Restriction to leisure [44]	p = 0.04	Undergoing ND involving sacrifice of one or both sternocleidomastoid muscles (in the case of bilateral ND) is a risk factor for being restricted in leisure participation post-surgery
Cluster variable: shoulder flexion and abduction active range of motion at discharge from hospital PLUS non-SND PLUS presence of shoulder droop	SDQ at 4 months post-surgery [51]	p = 0.007	Displaying reduced active shoulder flexion and abduction range and a shoulder droop at discharge home from either RND or MRND surgery is a risk factor for a higher score on the SDQ (i.e. worse shoulder function)
Cluster variable: pain on external rotation of the shoulder and shoulder pain measured on a numerical rating scale	SDQ at 4 months post-surgery [51]	p = 0.03	Eliciting pain on external rotation of the shoulder and reporting higher levels of shoulder pain on a numerical rating scale is a risk factor for a higher score on the SDQ (i.e. worse shoulder function)
Shoulder Disability Questionnaire score at baseline	SDQ at 4 months post-surgery [51]	p = 0.04	Reporting a score above zero on the SDQ prior to ND (i.e. reporting pre-existing shoulder dysfunction) is a risk factor for a higher score on the same outcome at 4 months post-surgery (i.e. worse shoulder function)
Head and neck or shoulder and arm pain at 3 or 12 months post-treatment	Head and neck or shoulder and arm pain at 2 years post-treatment [45]	3 months: p = 0.005 12 months: p = 0.01	Reporting the presence of head and neck or shoulder and arm pain at 3 months or 12 months post-treatment is a risk factor for reporting head and neck or shoulder and arm pain at 2 years post-treatment
Radiation therapy (pre-surgery or post-surgery)	NDII [49]	p = 0.003	Undergoing radiation therapy is a risk factor for a lower (i.e. worse) HRQOL
Radiation therapy (pre-	FACIT-HN Scale [36]	coeff = -0.57; $p \leq 0.05$	Undergoing radiation therapy is a risk factor for a lower

Risk factor	Associated outcome	Coefficient (coeff or OR) and p value (if available) (as originally reported in the referenced article)	Explanation of association
surgery or intra-operatively)			score on the FACIT-HN Scale (i.e. worse quality of life)
Chemotherapy	NDII [49]	$p = 0.03$	Undergoing chemotherapy is a risk factor for a lower score on the NDII (i.e. worse quality of life)
Chemotherapy (pre-surgery)	FACIT-HN Scale [36]	coeff = -0.45; $p \leq 0.05$	Undergoing chemotherapy is a risk factor for a lower FACIT-HN Scale score (i.e. worse quality of life)
Patient weight	Constant Shoulder Score [41]	$p < 0.0001$	Being underweight as a patient is a risk factor for a lower Constant Shoulder Score (i.e. worse shoulder function)
Advanced stage disease	NDII [49]	$p = 0.006$	Having advanced stage disease is a risk factor for a lower NDII score (i.e. worse quality of life)
T3-T4 tumour stage	Pain score within the HNQOL questionnaire [43]	$p = 0.04$	Presenting with T3-T4 stage disease is a risk factor for higher HNQOL scores (i.e. better quality of life)
Oral cavity or pharynx primary tumour	Severity of pain (head and neck or shoulder and arm) at diagnosis [45]	$p = 0.02$	Being diagnosed with an oral cavity or pharynx primary tumour (as opposed to a laryngeal primary tumour) is a risk factor for increased severity of head and neck or shoulder and arm pain at diagnosis
Hypopharynx primary tumour	Myofascial pain syndrome [40]	$p = 0.008$	Being diagnosed with a hypopharyngeal primary tumour (as opposed to a n oral cavity/oropharyngeal or laryngeal primary tumour) is a risk factor for experiencing myofascial pain syndrome post-surgery
Clinically positive lymph nodes	Myofascial pain syndrome [40]	$p = 0.024$	Presenting with clinically positive lymph nodes is a risk factor for experiencing myofascial pain syndrome post-surgery
Reconstruction	Shoulder flexion range of motion (not specific as active or passive) [42]	coeff (95% CI) = -24.5 (25.5, -13.4); p value not listed	Undergoing ND with reconstruction is a risk factor for loss of shoulder flexion range of motion post-surgery
Total laryngectomy	NDII [69]	vs partial laryngectomy $p = 0.002$ vs glossectomy $p = 0.043$	Undergoing total laryngectomy (as opposed to partial laryngectomy or glossectomy) is a risk factor for lower scores on the NDII (i.e. worse quality of life)

Risk factor	Associated outcome	Coefficient (coeff or OR) and p value (if available) (as originally reported in the referenced article)	Explanation of association
Male gender	Shoulder pain [36]	coeff = 0.39; $p \leq 0.05$	Being male is a risk factor for increased shoulder pain post-surgery

ND = neck dissection; SND = selective neck dissection; MRND = modified radical neck dissection; RND = radical neck dissection; CNXI = accessory nerve; HRQOL = health-related quality of life; SDQ = Shoulder Disability Questionnaire; FACIT-HN = Functional Assessment of Chronic Illness Therapy – Head and Neck; NDII = Neck Dissection Impairment Index; HNQOL = Head and Neck Quality of Life.

Appendix Five: These variables were found NOT to be risk factors for various outcomes related to the shoulder and neck.

Variable	Variable was found NOT to be a risk factor for the following outcomes:
No ND	Shoulder-sub-score of the UW QOL questionnaire (Portuguese version) [39] SDQ score above zero [57] Neck stiffness, constriction, appearance, numbness [44] Shoulder or neck pain, shoulder drop [44] Reaching hand for above object [44]
SND	Neck Dissection Impairment Index [49] Constant Shoulder Score [50] Shoulder flexion and abduction ROM (not specified as active or passive), shoulder elevation and abduction strength [68] Shoulder pain, abduction ROM (not specified as active or passive) [42]
SND I-III	Shoulder or neck pain, neck numbness, shoulder drop, reach hand for above object [44]
SND II-IV	Shoulder drop [44]
SND II-V	Shoulder drop [44]
SND VI	Shoulder-sub-score of the UW QOL questionnaire (Portuguese version) [39]
MRND	Shoulder drop [44] Constant Shoulder Score [50] Shoulder flexion and abduction ROM (not specified as active or passive), shoulder elevation and abduction strength [68]
CNXI-preserving ND	Upper extremity activities of daily living on a locally derived 16-item questionnaire [67] Restriction to work, restriction to leisure [44] Pain score within the Head and Neck Quality of Life questionnaire, single shoulder or neck pain item within the Head and Neck Quality of Life questionnaire [43]
Status of CNXI	Restriction to dressing, restriction to combing hair [44]
Status of SCM	Restriction to combing hair [44]
Preservation of 1 or both SCM	Restriction to dressing, restriction to leisure [44]
Status of IJV	Restriction to dressing, restriction to work, restriction to leisure [44]
No reconstruction	Shoulder flexion ROM (not specified as active or passive) [42]
Shoulder flexion and abduction AROM pre-surgery	SDQ at 4 months post-surgery [51]
Neck rotation and E AROM pre-surgery and at discharge from hospital	SDQ at 4 months post-surgery [51]
RAND pre-surgery	SDQ at 4 months post-surgery [51]
Age	Shoulder-sub-score of the UW QOL questionnaire (Portuguese version) [39]

Variable	Variable was found NOT to be a risk factor for the following outcomes:
	Constant Shoulder Score [41, 50] NDII [49] SDQ at 4 months post-surgery [51] Head and neck or shoulder and arm pain at 2 years post-treatment [45] Myofascial pain syndrome [40] Shoulder ROM (not specified as active or passive), shoulder pain and stiffness [69]
Sex or gender	Shoulder-sub-score of the UW QOL questionnaire (Portuguese version) [39] Constant Shoulder Score [41] NDII [49] SDQ at 4 months post-surgery [51] Head and neck or shoulder and arm pain at 2 years post-treatment [45] Myofascial pain syndrome [40]
Female gender	Shoulder pain [36]
American Society of Anaesthesiologists classification	Shoulder-sub-score of the UW QOL questionnaire (Portuguese version) [39]
Tumour stage	Constant Shoulder Score [41] Single shoulder or neck pain item within the HNQOL questionnaire [43] Myofascial pain syndrome [40] Shoulder ROM (not specified as active or passive), shoulder pain and stiffness [69]
T0-2 tumour stage	Pain score within the HNQOL questionnaire [43]
Nodal stage	Pain score within the HNQOL questionnaire, single shoulder or neck pain item within the HNQOL questionnaire [43]
Disease stage	Head and neck or shoulder and arm pain at 2 years post-treatment [45]
Status of disease at follow up assessment	Head and neck or shoulder and arm pain at 2 years post-treatment [45]
Tumour site	Constant Shoulder Score [41] NDII [49]
Oral cavity/oropharynx primary tumour	Myofascial pain syndrome [40]
Laryngeal primary tumour	Myofascial pain syndrome [40] Head and neck or shoulder and arm pain at diagnosis [45]
Type of primary surgery	Shoulder range of motion (not specified as active or passive) [69]
Partial laryngectomy	NDII [69]
Glossectomy	NDII [69]

Variable	Variable was found NOT to be a risk factor for the following outcomes:
Time since treatment/surgery	Shoulder-sub-score of the UW QOL questionnaire (Portuguese version) [39] Constant Shoulder Score [41]
Undergoing surgery	Head and neck or shoulder and arm pain at 2 years post-treatment [45] Myofascial pain syndrome [40]
Undergoing surgery and radiation therapy	Head and neck or shoulder and arm pain at 2 years post-treatment [45] Myofascial pain syndrome [40]
Undergoing chemoradiation therapy	Myofascial pain syndrome [40]
Undergoing surgery and chemoradiation therapy	Myofascial pain syndrome [40]
Radioactive iodine therapy	Shoulder-sub-score of the UW QOL questionnaire (Portuguese version) [39]
Radiation therapy	Shoulder ROM (not specified as active or passive) [67] SDQ at 4 months post-surgery [51] SDQ score above zero [57] Head and neck or shoulder and arm pain at 2 years post-treatment [45] Myofascial pain syndrome [40] Shoulder flexion and abduction ROM (not specified as active or passive), shoulder elevation and abduction strength [68] Shoulder pain and stiffness [69]
Operation side (left or right)	Shoulder ROM (not specified as active or passive), shoulder pain and stiffness [69]
Hand dominance	Constant Shoulder Score [41, 50]
Body mass index	NDII [49]
Weight loss	Head and neck or shoulder and arm pain at 2 years post-treatment [45]
Diet	Head and neck or shoulder and arm pain at 2 years post-treatment [45]
Recruitment centre	SDQ at 4 months post-surgery [22]
Smoking and alcohol history	Head and neck or shoulder and arm pain at 2 years post-treatment [45] Myofascial pain syndrome [40]
Residential history	Head and neck or shoulder and arm pain at 2 years post-treatment [45]
Social situation	Head and neck or shoulder and arm pain at 2 years post-treatment [45]
Occupational history	Head and neck or shoulder and arm pain at 2 years post-treatment [45]

ND = neck dissection; SND = selective neck dissection; MRND = modified radical neck dissection; SCM = sternocleidomastoid; IJV = internal jugular vein; F = flexion; E = extension; Abd = abduction; ROM = range of motion; AROM = active range of motion; CNXI = accessory nerve; UW QOL = University of Washington Quality of Life; SDQ = Shoulder Disability Questionnaire; NDII = Neck Dissection Impairment Index; HNQOL = Head and Neck Quality of Life.